CHAPTER IV
THE ABIOTIC PARAMETERS

INTRODUCTION:

All organisms and the communities are directly or indirectly affected by the physical characteristics of their environment (Gillis *et al.*, 2008). Thus, the study of interactions between biotic and abiotic factors become essential to understand the community structure of an ecosystem (Dunson and Travis,1991). In wetland ecosystem the biotic factors are mostly dependent on the seasons and hydrology (Hussain, 1995). The changes in key physical and chemical parameters at the landscape scale are also known to affect aquatic community and ecosystem attributes such as species richness, its range and biodiversity. Ultimately these changes alter corresponding food web structures at the primary and secondary production levels (Wrona *et al.*, 2006). The climate change is also known to play an important role in the alterations of abiotic factors (Prowse *et al.,* 2006). Thus, consideration of water quality is important in water bird habitat evaluation (Hutchinson, 1957; Wetzel, 1975; Nagarajan and Thiyagesan, 1996).

The physical and chemical properties of freshwater body are characteristics of the climatic, geochemical, geomorphological and pollution conditions prevailing in the drainage basin and the underlying aquifer (Ramchandra *et al.*, 2002). These characteristics with natural or manmade changes determine the quality of water (Anonymous, 2003). The major factors for these changes are often due to human mediation like the agricultural activities, the domestic activities and the industrial run off. Hence, for understanding the habitat, baseline information of various components of the ecosystem including abiotic parameters were conducted. The present chapter deals with the factors such as the Temperature, Water Cover, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, Acidity, Alkalinity (Hydroxyl alkalinity and Bicarbonate alkalinity), Total Hardness, Calcium Hardness, Salinity, Dissolved Oxygen (DO), Dissolved Carbondioxide (CO_2), Chlorides (Cl^-), Nitrites (NO_2^{-3}) and Nitrates (NO_3^{-2})., Phosphates (PO_4^{-3}).

THE PHYSICAL AND OTHER AGGREGATE PARAMETERS:

Temperature: It plays an important role in any ecosystem by altering the primary productivity. The solar radiation and atmospheric temperature bring about spatial and temporal changes in temperature, setting up convection currents and thermal stratification (Ramchandra, *et al.*, 2002). ***Water Cover:*** Change in the water cover affects abiotic factors in turn influencing biota (Shurin, 2000). ***Total Solids (TS):*** TS is the term applied to the material residues left in the vessel after evaporation of water sample and its subsequent drying in an oven at a defined temperature. Total solids include ***Total Dissolved Solids (TDS)*** and ***Total Suspended Solids (TSS):*** These are actually the nonfiltrable and residue solids respectively (APHA, 1998). The high total solid content in water results in turbidity that reduces the visibility in the water thereby makeing it difficult for the organisms to survive (APHA, 1998). ***pH:*** It indicates the acidic or basic (alkaline) nature of water. It is one of the most important parameters studied to evaluate chemistry of the water (Ramchandra, *et al.*, 2002). The role of hydrogen and hydroxide ion concentrations in aquatic toxicity is well known (Belanger and Cherry, 1990). Nagarajan and Thiyagesan (1996) have correlated water bird density of an estuarine ecosystem with soil pH. ***Acidity:*** Acidity of water is its quantitative capacity to react with a strong base at a designated pH (APHA, 1998). The anthropogenic acidification is reported to change the vegetation and prey base resulting in change in bird community (Doherty *et al.*, 2000). Contrariwise, ***Alkalinity*** of water is its ability to neutralize a strong acid. The chief components contributing to the alkalinity of most natural freshwater are carbonates (CO_3^{-2}) and bicarbonate (HCO_3^{-1}). Changes in alkalinity are considered as the amount of titratable base expressed as milli equivalents/liter. Alkalinity is mainly measured in two forms, the hydroxyl alkalinity that is attributed to OH^- and bicarbonate alkalinity that is attributed to carbonates and bicarbonates present in water. Direct comparisons of alkalinity are difficult because of differing ionic constituents of different water bodies (Dunn, 1965). It has been reported that the alkaline ponds support high Rotifer density and low species richness (Sladecek, 1983). Further, it has also been noted by George and Heaney, (1978) that the highly alkaline ponds promote the growth of Phytoplankton resulting in the algal bloom. ***Salinity:*** Salinity is considered as a measure of the mass of dissolved salts in a given mass of solution (APHA, 1998). The effect of salinity on invertebrate community of the closed inland wetland biota have been well established (Verschuren *et al.*, 2000).

The total biomass of the submerged communities decreases exponentially, and the species richness decreases linearly with increasing salinity (Grillas *et al.*, 1993). ***Hardness:*** It is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate in milligrams per liter.

THE INORGANIC NON-METALLIC CONSTITUENTS:

Dissolved Oxygen (DO): According to McManus *et al.* (1996) and Ramchandra *et al.* (2002); DO, the important respiratory gas for biota, is a sensitive tracer of the physical, chemical and biological processes occurring in an aquatic system. Due to photosynthetic activities (Jenkins and Goldman, 1985; Emerson *et al.*, 1991) and with the addition from atmosphere, excess of oxygen is likely to occur at the surface while due to consumption of oxygen by detritus feeder or decomposers and various fauna, paucity of oxygen may take place at bottom of a wetland (McManus *et al.,* 1996). Further, in a lake, seasonal changes in oxygen content have a direct effect on both physical and chemical conditions. This in turn control algal and organic productivity in general (Happey, 1970). ***Carbondioxide*** the other respiratory gas, is known to fluctuate in the water and may have direct impact on the plant growth and hence indirectly influence various faunal communities. ***Chlorides,*** in the form of chloride ions (Cl^-), are one of the major inorganic anions in natural/ waste water. High chloride content may indicate the pollution by sewage/ some industrial waste or an intrusion of seawater/ other saline water (APHA, 1998). Highly chlorinated water is not suitable for the survival of freshwater stenohaline organisms. ***Nitrogen*** is one of the important component of biogeochemical cycle and is important nutrient for plants. Nitrogen occur in water as a result of decreasing oxidation state, as nitrate, nitrite, ammonia and organic nitrogen. All these forms are interconvertible and are components of the nitrogen cycle. Nitrate and nitrite the two biochemically interconvertable components of total oxidized nitrogen are the sum of nitrate and nitrite nitrogen. Nitrate and Nitrite are considered here. ***Nitrate*** generally occurs in trace quantities in surface water but also attains high levels in some groundwater. It is found in small amounts in fresh domestic wastewater but the effluent from nitrifying biological treatment plants have high concentrations. ***Nitrite*** is an intermediate stage in oxidation of nitrogen, both in the oxidation of ammonia to nitrate as well as in the reduction of nitrate. Nitrate and Nitrite serve as nutrients and can change the plant community of a wetland. ***Phosphate:*** Phosphate occurs in natural waters and in wastewaters. Small amount of phosphate arise from a variety of sources but primarily by biological processes from organic phosphorous. It is essential for the growth of organisms and forms the nutrient limiting the primary productivity of a water body (APHA, 1998). Phosphorus has been identified as the limiting nutrient for phytoplankton development (Khan and Ansari, 2005) however, when present in large quantity in surface waters it is associated with the excessive growth of algae (eutrophication and then algal bloom) (Lean, 1973; Ambasht and Ambasht, 1992).

MATERIALS AND METHODS:

Water was collected from three field stations selected at each wetland. The parameters such as Temperature, pH, CO_2 were analyzed and DO was fixed at the site itself. Analysis of other necessary parameters were carried out in the laboratory. Samples were brought in an ice box so as to retain their chemical properties.

***PHYSICAL AND OTHER AGGREGATE PARAMETERS*:** Temperature, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, Acidity, Hydroxyl Alkalinity, Bicarbonate Alkalinity, Salinity, Total Hardness and Calcium Hardness.

Temperature: Temperature was measured using the Mercury thermometer and was noted in °C.

Water Cover: The water cover was estimated visually in terms of percentage as compared to the maximum filled level(Plate IV A).

Total Solids (TS): (APHA, 1998)

The total solids include the total suspended solids and the total dissolved solids. The residue that is left after the evaporation of the sample water in a vessel including the suspended solids as well as the dissolved solids are the total solids. About 10 ml well-mixed sample was taken into a pre-weighed evaporating dish and evaporated to dryness at 103-105°C. The evaporating dish was cooled and accurately weighed to constant weight. The difference in the two weights is considered as TS. It is calculated as:

$$\text{Total Solids (mg/l)} = \frac{(W_2 - W_1) \times 1000}{\text{Amount of Sample taken (ml)}}$$

W_1= Weight of empty evaporating dish.

W_2= Weight of dried residue + evaporating dish

Total Dissolved Solids (TDS): (APHA, 1998)

A known volume of the well-mixed sample (10ml) was measured, filtered and evaporated to dryness at 103-105 °C. The evaporating dish was cooled and constant weight was recorded. The difference in the two weights is considered as TDS and it is calculated by using formula as above.

Total Suspended Solids (TSS): (APHA, 1998)

Suspended solids are the portions of the Total solids that are retained on a filter paper after filtering the sample. Alternatively the difference between the total solids and the total dissolved solids can also be taken as total suspended solids. Hence, TSS is calculated as follows.

Total Suspended Solids TSS mg/l = TS mg/l-TDS mg/l

Total Suspended Solids were measured for the 2nd year of the study.

pH:

In situ estimation of the pH was carried out by dipping the digital pH meter (pH Scan Eutech Instruments) about 10 cms. below the surface of water.

Estimation of Acidity: (Titrimetric method, APHA, 1998)

Hydrogen ions present in a sample as a result of dissociation/ hydrolysis of solutes react with standard alkali added to it. Acidity thus depends on the end-point pH/ indicator used. For routine control titrations or rapid preliminary estimates of acidity, the colour change of an indicator is used to find out the end point.

In 10ml of sample, 2 to 4 drops of phenolphthalein as indicator were added and titrated against 0.02 N NaOH solution. Wherever necessary the sample were made colourless with the help of charcoal. Colour change from colourless to pink was taken as the end point and acidity was calculated using following formula.

$$\text{Acidity as mg } CaCO_3\text{ /l} = \frac{\text{B.R X 1000}}{\text{Amount of Sample taken (ml)}}$$

B.R. = Burette reading (Amount of titrant used).

Estimation of Hydroxyl and Bicarbonate Alkalinity: (***Titrimetric Method*** - APHA, 1998)

Total alkalinity is the sum of Hydroxyl alkalinity and Bicarbonate alkalinity. Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Thus Alkalinity also depends on the end-point pH. To estimate Hydroxyl alkalinity, in 50ml of sample 3 to 4 drops of Phenolphthalein indicator were added and titrated against 0.02N H_2SO_4. If the solution remained colour less then the hydroxyl alkalinity was considered as zero. Colour change from pink to clourless was noted down as the burette reading (A) for calculation of hydroxyl alkalinity. To estimate bicarbonate alkalinity, few drops of methyl orange indicator were added to 50ml of sample in which the Phenolphthalein alkalinity had been determined and titrated against 0.02N H_2SO_4. The end point was noted with change in yellow colour to orange at pH 4.6. as burette reading (B).

$$\text{Hydroxyl alkalinity as mg } CaCO_3/l = \frac{A \times N \times 50 \times 1000}{\text{Amount of Sample taken (ml)}}$$

$$\text{Bicarbonate alkalinity as } CaCO3 \text{ mg/l} = \frac{B \times N \times 50 \times 1000}{\text{Amount of Sample taken (ml)}}$$

A is Burette reading for phenolphthalein alkalinity.

B is Burette reading for Methyl orange alkalinity.

N is normality of Sulphuric acid (0.02).

50 is equivalent weight of $CaCO_3$

Salinity (APHA, 1998) it is calculated from chloride value as 1.8055 X Chloride (Page 130).

Estimation of Total Hardness: (EDTA Titrimetric Method- APHA, 1998)

Ethylene di-amine tetra acetic acid (EDTA) and its sodium salts form a chelated soluble complex when added to a solution of certain metal cations. A small amount of a dye such as Eriochrome Black T/ Calmagite is added to the aqueous solution containing calcium and magnesium ions, at pH of 10.0. This turns the solution wine red. With further addition of titrant, the solution turns from wine red to blue, indicating the end point.

For the estimation of total hardness, in 50 ml of sample, 1 to 2ml of buffer solution and a pinch of Eriochrome Black T (used as an indicator) were added. After the wine red colour appeared the mixture was titrated against EDTA, stirring continuously till end point of wine red to blue appeared. The hardness was calculated using following formula.

$$\text{Hardness as mg } CaCO_3 / l = \frac{A \times N \times 1000}{\text{Amount of sample taken (ml)}}$$

Where A = ml of titrant (EDTA) used.

N= Normality of EDTA.

Estimation of Calcium Hardness: (***EDTA Titrimetric Method*** -APHA, 1998)

When EDTA is added to water containing both calcium and magnesium, it combines first with the calcium. Calcium was determined directly with EDTA when pH was made sufficiently high. At this pH the magnesium gets largely precipitated as the hydroxide. The indicator used (Murexide indicator) combines only with calcium. Hence when all Calcium is used up colour changes from pink to violet indicating end point.

To estimate calcium hardness, to 50 ml of sample 3ml of 0.1 N NaOH (upto pH 12) and 0.2 to 0.4 gm of murexide indicator were added and titrated against 0.02 N EDTA. As per need charcoal was used to remove turbidity. The pinkish tinge disappears and violet colour appeared. The end point was noted as B. The hardness is calculated as

$$\text{Hardness mg } CaCO_3 /l= \frac{B \times N \times 1000}{\text{Amount of sample taken (ml)}}$$

Where B = ml of titrant (EDTA) used.

N = Normality of EDTA (0.02N)

INORGANIC NON-METALLIC CONSTITUENTS: Dissolved Oxygen, Free Carbon dioxide, Chloride, Nitrates, Nitrites and Phosphates.

Estimation of Dissolved Oxygen: (Wrinkler's Methods- APHA, 1998)

The magnesium sulphate reacts with the alkali (KOH) to form white precipitates of manganous hydroxide. In presence of oxygen in highly alkaline solution, the white manganous hydroxide is oxidized to brown coloured manganese oxyhydrate. This occurs in direct proportion to the amount of oxygen present. In strong acidic medium, manganic ions are freed and they react with the iodine ions of potassium iodide to release free iodine.

The amount of free iodine is equivalent to the amount of oxygen present in the water and can be determined by titration with sodium thiosulphate.

For the estimation of Dissolved Oxygen the water was collected with care in BOD bottles without bubble formation. The DO was then fixed at the site itself by adding 1 ml each of Manganese Sulphate and Alkali-iodide azide reagents. The precipitates formed were dissolved by adding 2 ml of concentrated sulphuric acid. From this 50ml sample was taken and titrated against 0.1N Sodium thiosulphate. To estimate iodine generated starch was used as indicator and the end point was noted as the solution turned blue to colourless. The DO is calculated using following formula.

$$\text{DO mg/l} = \frac{\text{B. R. X N X 1000}}{\text{Amount of Sample taken (ml)}}$$

B. R. = Burette Reading (Amount of titrant used).
N = Normality of Sodium thiosulphate.

Free Carbondioxide (APHA, 1998)

Surface water normally contains less amount of free carbondioxide as compared to ground water. Free carbondioxide reacts with sodium hydroxide to form sodium bicarbonate. In 50 ml sample 2 to 3 drops of Phenolphthalein were added and the sample was titrated against 0.02 N Sodium hydroxide. The end point is noted as colourless to pink. The free carbondioxide is calculated using following formula.

$$\text{mg } CO_2/l = \frac{\text{B. R. X N X 44 X 1000}}{\text{Amount of Sample taken (ml)}}$$

B. R= Burette Reading (Amount of titrant used).
N= Normality of Sodium Hydroxide (0.02 N).
44 is equivalent weight of CO_2

(The estimation of Carbondioxide was carried out only for the 2nd year of study hence the number of observation is low.)

Estimation of Chloride : (***Argentometric Titremetric*** method- APHA, 1998)

In a neutral or slightly alkaline solution, Choride is estimated with Silver nitrate as titrant using potassium chromate as an indicator. Silver chloride is precipitated quantitatively before red silver chromate is formed.

In 50ml of sample, 1ml of K_2CrO_4 indicator was added and titrated against 0.028N $AgNO_3$ till brick red precipitates were formed. The formula used to calculate mg Cl^-/l is

$$\text{mg } Cl^-/l = \frac{\text{B.R. X N X35.45 X 1000}}{\text{Amount of sample taken (ml)}}$$

N = Normality of Silver Nitrate.
B. R. = Burette reading (Amount of titrant used).
35.45 is the equivalent weight of Chloride.

Estimation of Nitrogen: (APHA, 1998)

Estimation of Nitrates (NO_3^-N): (Cadmium Reduction Method)

Nitrate (NO_3^-) is reduced to nitrite (NO_2^-) in the presences of Cadmium (Cd). This method uses commercially available Cd granules treated with copper sulfate ($CuSO_4$) and packed in a glass column. The Nitrite (NO_2^-) produced is determined by diazoitizing it with colour reagent containing sulfanilamide coupled with N-(1-naphthyl)-ethylenediamine dihydrochloride (NEDD) to form highly coloured azo dye. The colour developed is measured colorimetrically. A correction was made for any NO_2^- present in the sample by analyzing the sample without the reduction step.

In this method 50 ml sample was taken and passed through the Cadmium column. The initial 10 ml was discarded and then 25 ml was collected for estimation. To this 2 ml of colour reagent was added and optical density was measured at 543 nm with colorimeter model Photochem 5. A reagent Blank is used to set the instrument. The Nitrate was calculated using following formula.

$$NO_3^-N \text{ mg/l} = \frac{\text{O.D X Factor}}{\text{Amount of sample taken (ml)}}$$

Factor is obtained by plotting standard graph.

Nitrites: (Colorimetric Method- APHA, 1998)

Nitrite is determined by the formation of reddish purple azo dye produced at pH 2.0-2.5 with colour reagent.

To estimate Nitrites 50 ml of sample was taken in a beaker and 2 ml of colour reagent was added to it. The colour developed was read immediately at 543 nm using colorimeter model Photochem 5 indicating O.D. A standard graph is plotted to obtain factor. A reagent blank is run to set the instrument. The Nitrites are calculated as

$$NO_2^-N \text{ mg/l} = \frac{\text{O.D X Factor}}{\text{Amount of sample taken (ml)}}$$

Estimation of Phosphate Phosphorous: (APHA, 1998)

When the Ammonium Molybdate is added to the sample, Molybdophosphoric acid is formed. This is reduced by stannous chloride to intensely coloured molybdenum blue which is measured colourimetrically.

In a conical flask containing 100 ml of sample, 4ml of strong acid and 4ml of ammonium molybdate were added followed by 10 drops $SnCl_2$. The blue colour developed was measured after 10 minutes at 690 nm with colorimeter model Photochem 5. It is necessary to make a standard graph before the analysis of sample to obtain the factor. The instrument was set by running a reagent blank.

The Phosphate are calculated as

$$PO_4^{-3} \text{ as mg/l} = \frac{\text{O.DX Factor}}{\text{Amount of Sample taken}}$$

For the convenience of analysis the data was pooled as four seasons: Summer (March, April and May), Monsoon (June, July and August), Postmonsoon (September, October and November) and Winter (December, January and

February). The results given are in the form of Mean ± SEM. The data is applied to ANOVA across the season with the help of Prism 3 soft ware (Graphpad software, San Diego, California U. S. A.). The correlation between various biotic parameters is also calculated with the help of SPSS 7.5/12 for windows.

The p value for ANOVA is non significant if $P > 0.05$ (ns), significant if $P < 0.05$ (*), significantly significant (**), if P is <0.001 and highly significant (***) if $p< 0.0001$.

RESULTS:

The abiotic factors at all the wetlands studied show variations depending on wetlands, whether it is an irrigation reservoir or a village pond, its geographic location as well as anthropogenic pressures (and topography especially at MVP). Seasonal variations are observed in each of the studied parameters.

Wadhwana Irrigation Reservoir (WIR):

The seasonal variations in Temperature; Water Cover, Total Solids, Total Dissolved Solids and Total Suspended Solids and pH are given in Fig. 4.1a. ***Temperature***: The water temperature shows highly significant variations ($P < 0.0001$, $F_{3,\,39}$ 19.30). The highest temperature 29.44 ± 0.2 °C is observed during monsoon and lowest 24.2 ± 0.6 °C during winter. While during summer and postmonsoon it was noted to be 28.3 ± 0.47 °C and 27.2 ± 0.4 °C respectively. The ***Water cover*** at WIR also varies highly significantly ($P < 0.0001$, $F_{3,\,50}$ 12.1) with maximum 93.7 ± 1.25 % during postmonsoon and minimum 60.5 ± 5.09 % during summer. During monsoon and winter it was 81.6 ± 6.8 % and 91.2 ± 1.3 % respectively. ***Total Solids*** in water of WIR were also found to vary highly significantly ($P < 0.0001$, $F_{3,57}$ 6.4). TS was highest during monsoon (1.7 ± 0.9 mg/l) and lowest during summer (0.26 ± 0.04 mg/l). During winter 0.42 ± 0.16 mg/l TS was, and in postmonsoon it was 0.29 ± 0.05 mg/l. ***Total Dissolved Solids*** followed a different trend than that of Total solids and showed insignificant variations over the year ($P > 0.05$, $F_{3,\,43}$ 2.8) with minimum 0.09 ± 0.04 mg/l

Fig. 4.1a: Seasonal variations in different physical aggregate parameters at Wadhwana Irrigation Reservoir from March 05 to May 07.

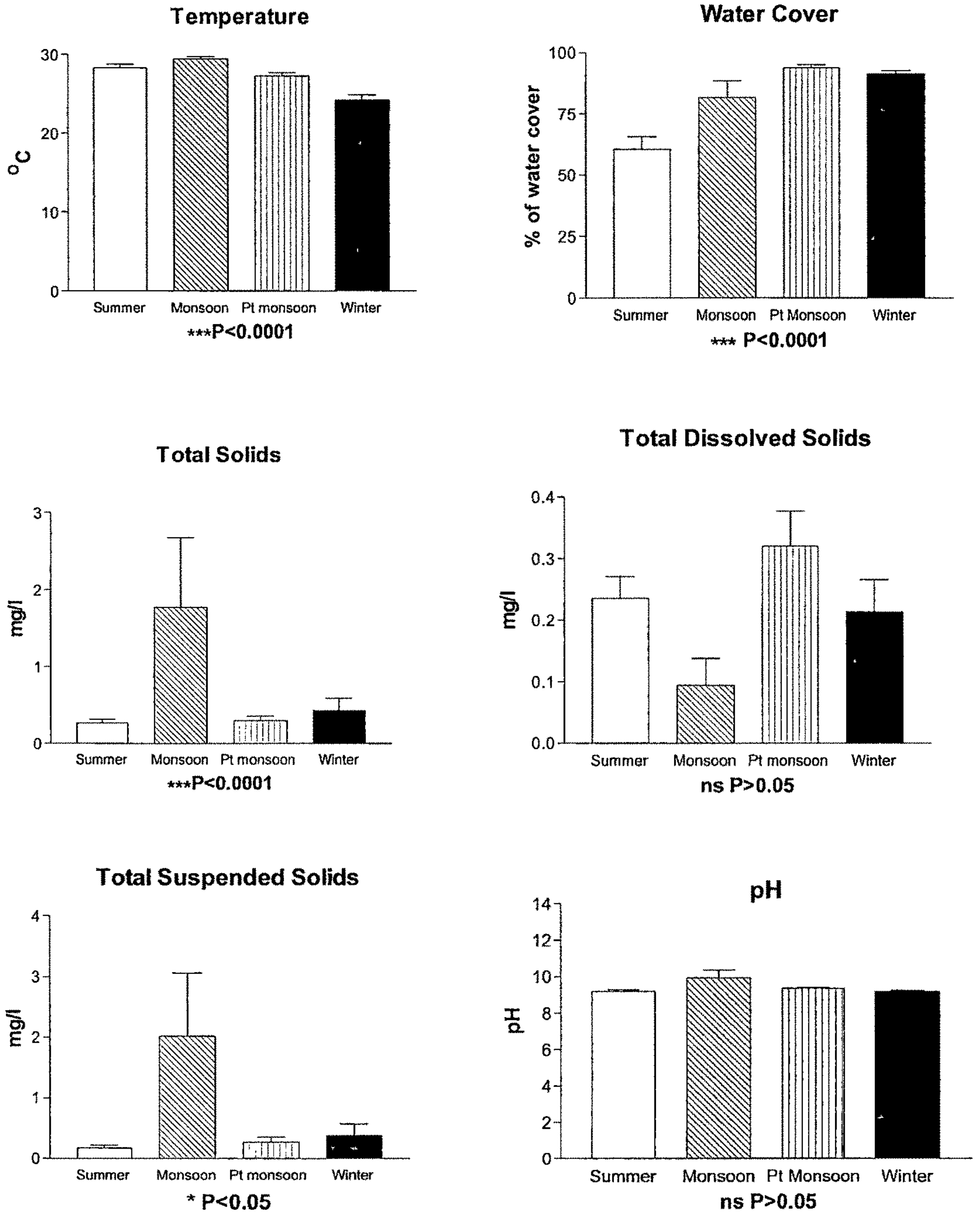
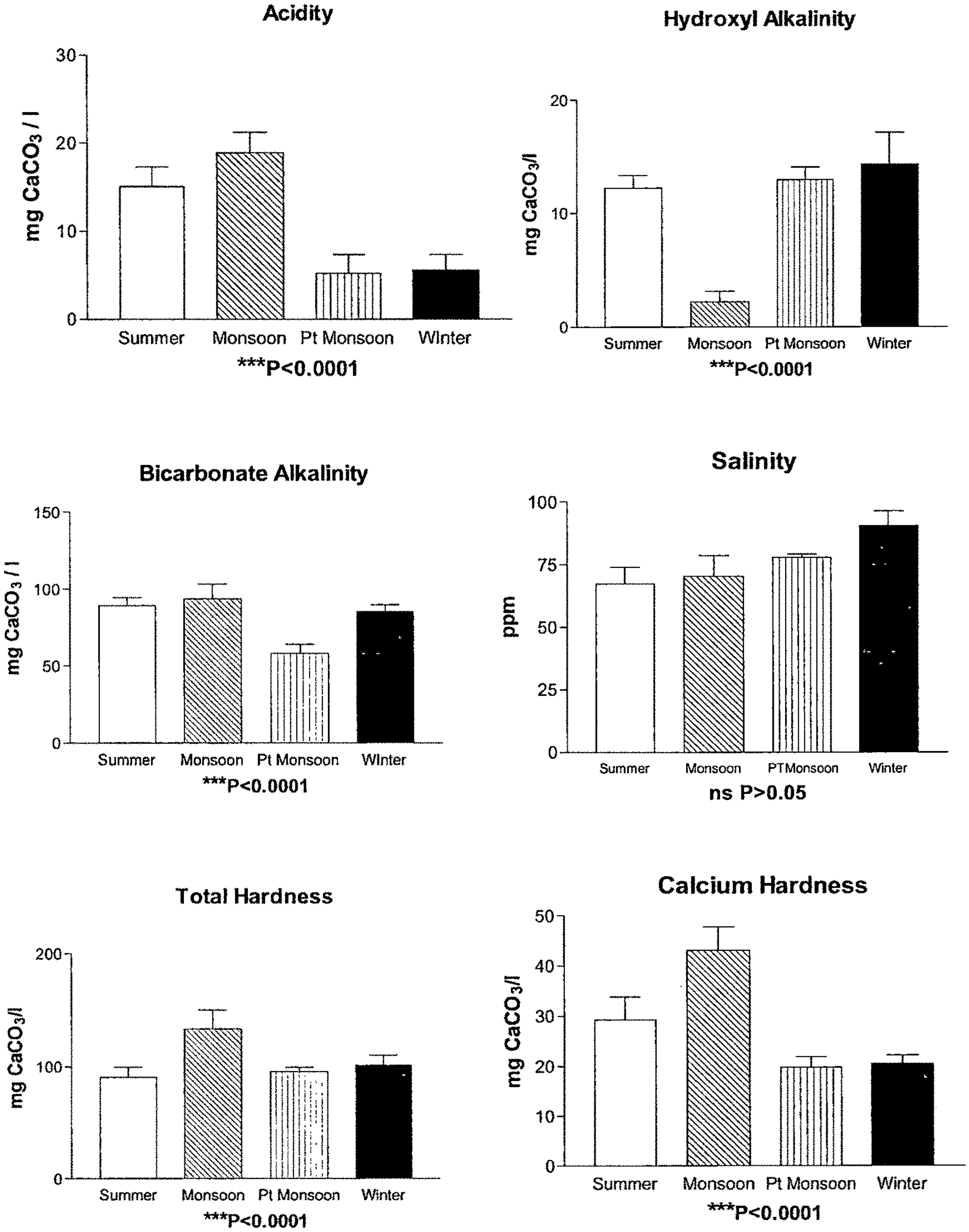


Fig. 4.1b: Seasonal variations in different physical aggregate Parameters at Wadhwana Irrigation Reservoir from March 05 to May 07.



Acidity

Hydroxyl Alkalinity

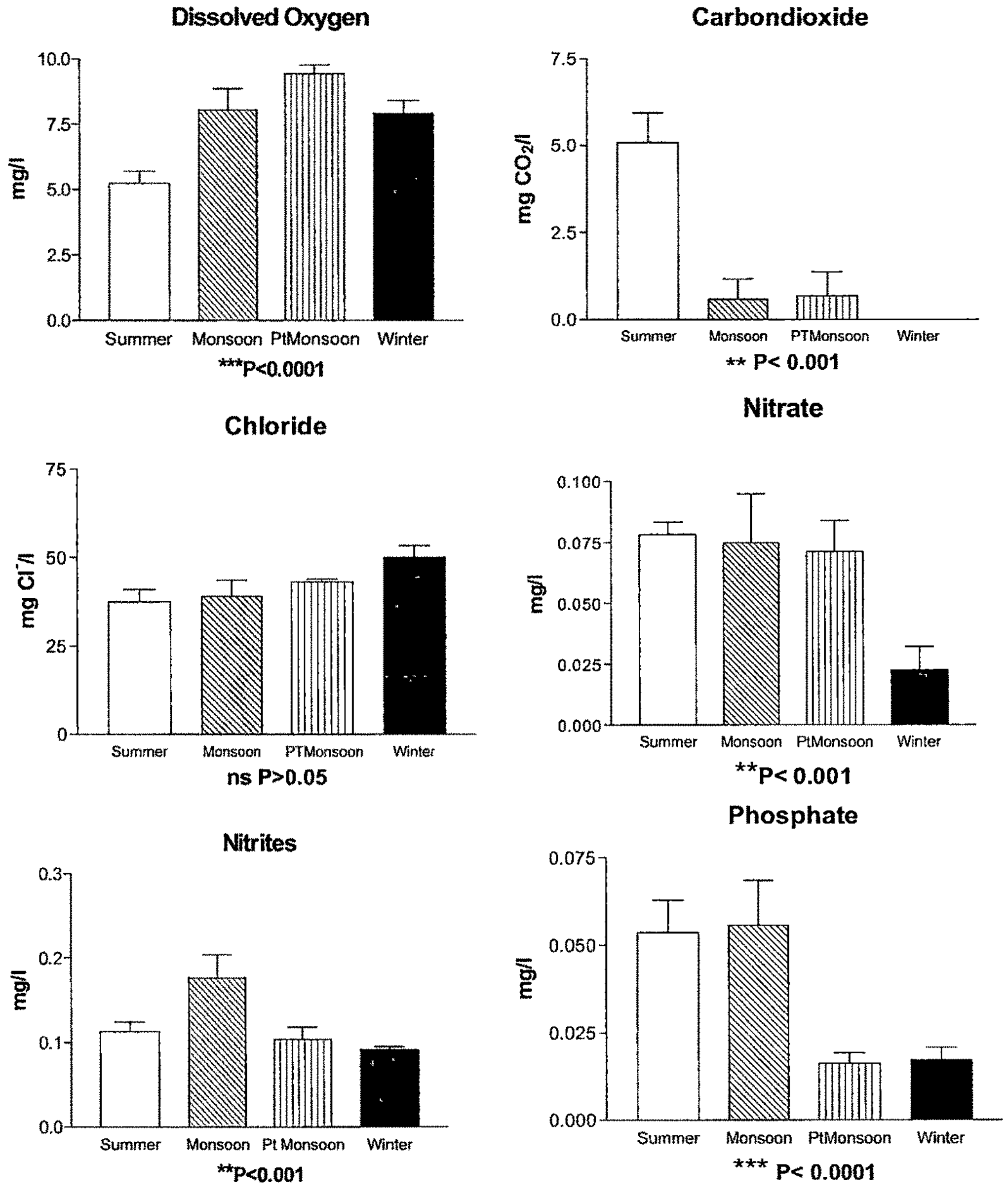
Bicarbonate Alkalinity

Salinity

Total Hardness

Calcium Hardness

Fig. 4.1c: Seasonal variations in different inorganic non-metallic constituents at Wadhwana Irrigation Reservoir from March 05 to May 07.



during monsoon and maximum 0.32 ± 0.06 mg/l during postmonsoon while during winter and summer TDS were 0.21 ± 0.05 mg/l and 0.23 ± 0.03 mg/l respectively.

Total Suspended Solids were maximum 2.02 ± 1.04 mg/l during monsoon and minimum 0.17 ± 0.04 mg/l during summer while during postmonsoon and winter TSS were 0.27 ± 0.07 mg/l and 0.38 ± 0.18 mg/l respectively. The variations over the season were significant ($P < 0.05$, $F_{3,22}$ 4.1).

pH of water at WIR was mainly basic and did not vary significantly ($P > 0.05$, $F_{3, 76}$ 2.6) over the seasons. The highest pH 9.9 ± 0.43 was noted during monsoon which was maintained during post monsoon at 9.37 ± 0.06, during winter at 9.20 ± 0.07 and summer at 9.1 ± 0.09.

Seasonal changes in acidity, Hydroxyl and bicarbonate alkalinity, Salinity and Total as well as Calcium hardness are shown in Fig. 4.1b. The ***Acidity*** that depends on hydrogen ion concentration shows highly significant variations ($P < 0.0001$, $F_{3, 119}$ 8.7) at WIR over the seasons with highest acidity noted during monsoon (18.8 ± 2.3 mg $CaCO_3$/l) and minimum during post monsoon (5.19 ± 2.14 mg $CaCO_3$/l). During winter it was low at 5.5 ± 1.76 mg $CaCO_3$/l and summer it was higher at 15.03 ± 2.2 mg $CaCO_3$/l. The ***Hydroxyl Alkalinity*** varies highly significantly ($P < 0.0001$, $F_{3, 127}$ 50.3) when the means over the seasons are compared. It was maximum during winter (14.3 ± 2.8 mg $CaCO_3$/l) and minimum during monsoon (2.2 ± 0.91 mg $CaCO_3$/l) while during post monsoon it was 12.9 ± 1.0 mg $CaCO_3$/l and during summer increased to 12.2 ± 1.1 mg $CaCO_3$/l. The

Bicarbonate Alkalinity also shows highly significant variations over the seasons ($P < 0.0001$, $F_{3,\ 133}$ 6.3). The WIR water was more alkaline during monsoon (93.7 ± 9.7 mg/l) and minimum alkaline in postmonsoon (58.06 ± 6.09 mg $CaCO_3$/l), while in winter it was 85.4 ± 4.5 mg/l and in summer it was 89.4 ± 4.9 mg/l. Though the ***Salinity*** shows no significant difference over the four seasons ($P > 0.05$, $F_{3,\ 133}$ 2.5) it was minimum during summer (67.4 ± 6.5 ppm) and started increasing non significantly from monsoon (70.3 ± 8.2 ppm) followed by postmonsoon (77.6 ± 1.4ppm) and reached maximum during winter (90.3 ± 6.0 ppm). ***Total Hardness*** showed seasonal oscillations and varied highly significantly ($P < 0.0001$, $F_{3,\ 125}$ 3.3) over the seasons in both the years of study. The total hardness was minimum during summer (90.60 ± 9.24 mg $CaCO_3$/l), increased to maximum during monsoon (133.60 ± 16.92 mg $CaCO_3$/l) and then decreased during post monsoon (95.69 ± 4.196 mg $CaCO_3$/l) and increased again marginally in winter (101.40 ± 9.043 mg $CaCO_3$/l). The ***Calcium hardness*** at WIR varies highly significantly over the season with $P < 0.0001$, $F_{3,\ 114}$ 7.8. The highest calcium hardness was noted during monsoon (43.05 ± 4.72 mg$CaCO_3$ /l) and the lowest during postmonsoon (19.8 ± 2.0 mg$CaCO_3$ /l) while during winter it was maintained at 20.53 ± 1.655 mg$CaCO_3$ /l and during summer it increased to 29.29 ± 4.55 mg$CaCO_3$ /l (Fig. 4.1b).

The seasonal variations in different inorganic non-metallic constituents at WIR are given in fig 4.1c. The ***Dissolved Oxygen*** content indicates the quality of a water body. Seasonal highly significant variations in DO ($P < 0.0001$, $F_{3,\ 115}$ 12.2) were noted at WIR (Fig. 4.1c). The maximum dissolved oxygen was found during postmonsoon 9.4 ± 0.32 mg/l and minimum 5.23±0.46 mg/l during summer. The dissolved oxygen during monsoon was 8.0 ± 0.81 mg/l, but in winter it was 7.92 ± 0.49 mg/l. Variations in the ***Carbondioxide*** in WIR water were significantly significant ($P < 0.001$, $F_{3,\ 13}$ 9.0) over all the four seasons. It was absent during winter and was maximum during summer at 5.0 ± 0.85 mg CO_2/l. During monsoon and postmonsoon it was obtained only once 2.93 and 4.1 mg CO_2/l respectively. The ***Chloride*** concentration varies insignificantly ($P > 0.05$, $F_{3,\ 134}$ 2.6) over the four seasons at WIR (Fig.4.1c). During summer the chloride concentration was minimum (37.4 ± 3.6 mg/l), it started increasing gradually from monsoon (39.0 ± 4.5 mg/l) followed by postmonsoon (43.1 ± 0.8 mg/l) and reached maximum in winter (50.1 ± 3.2 mg/l). The ***Nitrogen*** content was estimated as the Nitrates and the Nitrites. A significantly significant variation ($P < 0.001$, $F_{3,\ 73}$ 4.6) is observed over the seasons in the ***Nitrate*** concentrations during the study period. The high nitrate concentrations were noted during summer (0.078 ± 0.005 mg/l), monsoon (0.074 ± 0.019 mg/l) and post monsoon (0.071 ± 0.012 mg/l). This was low during winter (0.022 ± 0.009 mg/l). ***Nitrite*** the other component of nitrogen estimated, shows significantly significant variations ($P < 0.001$, $F_{3,\ 80}$ 5.8) over the seasons. The highest concentration of nitrite was found during monsoon (0.17 ± 0.027 mg/l) and lowest during winter (0.091 ± 0.00 mg/l). During summer it was 0.11 ± 0.01 mg/l which was maintained during post monsoon at 0.10 ± 0.014 mg/l. The ***Phosphates*** also show highly significant (P<

0.0001, $F_{3,\ 134}$ 7.9) differences. The highest concentration of phosphate in WIR waters was noted during monsoon (0.055 ± 0.012 mg/l) and minimum during postmonsoon (0.016 ± 0.0030 mg/l). This was maintained during winter (0.017 ± 0.003 mg/l) while it increased during summer (0.053 ± 0.0092 mg/l).

Timbi Irrigation Reservoir (TIR):

The seasonal variations in temperature, water cover, total solids, dissolved solids, suspended solids and acidity for TIR are given in Fig. 4.2a.

Temperature shows significant variations ($P < 0.05$, $F_{3,\ 33}$ 4.4) over four seasons. In monsoon the average temperature of water was 27.0 ± 0.3 °C, that remained unchanged in postmonsoon at 27.1 ± 0.8 °C, but decreased during winter to 24.6 ± 1.0 °C and was maintained during summer at 25.0 ± 0.7 °C. The ***Water cover*** shows highly significant variations at TIR ($P < 0.0001$, $F_{3,\ 49}$ 12.08), with highest water cover 88.3 ± 2.0 % noted during postmonsoon, followed by 73.3 ± 1.4 % during winter and got reduced to 61.6 ± 2.6% in summer. The water cover at TIR started increasing during monsoon (63.6 ± 6.6 %). At TIR the earthen dam was washed away during monsoon of the first year of study. ***Total Solids (TS)*** show insignificant variations ($P > 0.05$, $F_{3,\ 61}$ 0.6) over the four seasons. Higher TS were noted during summer (0.4 ± 0.22 mg/l) followed by monsoon (0.34 ± 0.11 mg/l), minimum during postmonsoon (0.15 ± 0.02 mg/l) and in winter (0.12 ± 0.01 mg/l). ***Total Dissolved Solids (TDS)*** showed significantly significant ($P < 0.001$, $F_{3,\ 54}$ 4.9) variations over the seasons. TDS was maximum during summer (0.37 ± 0.06 mg/l), started declining during monsoon (0.2 ± 0.03 mg/l) and reached to minimum level during postmonsoon (0.12 ± 0.03 mg/l) and remained at low level during winter (0.19 ± 0.04 mg/l). ***The Total Suspended Solids (TSS)*** at TIR varies insignificantly ($P > 0.05$, $F_{3, 18}$ 0.7) and were maximum during summer (0.95 ± 0.71 mg/l), followed by monsoon (0.57 ± 0.3 mg/l), postmonsoon (0.13 ± 0.02 mg/l) and were minimum during winter (0.08 ± 0.085 mg/l).

Figure 4.2a: The Seasonal variations in the different physical aggregate parameters at Timbi Irrigation Reservoir from February 2005 to March 2007.

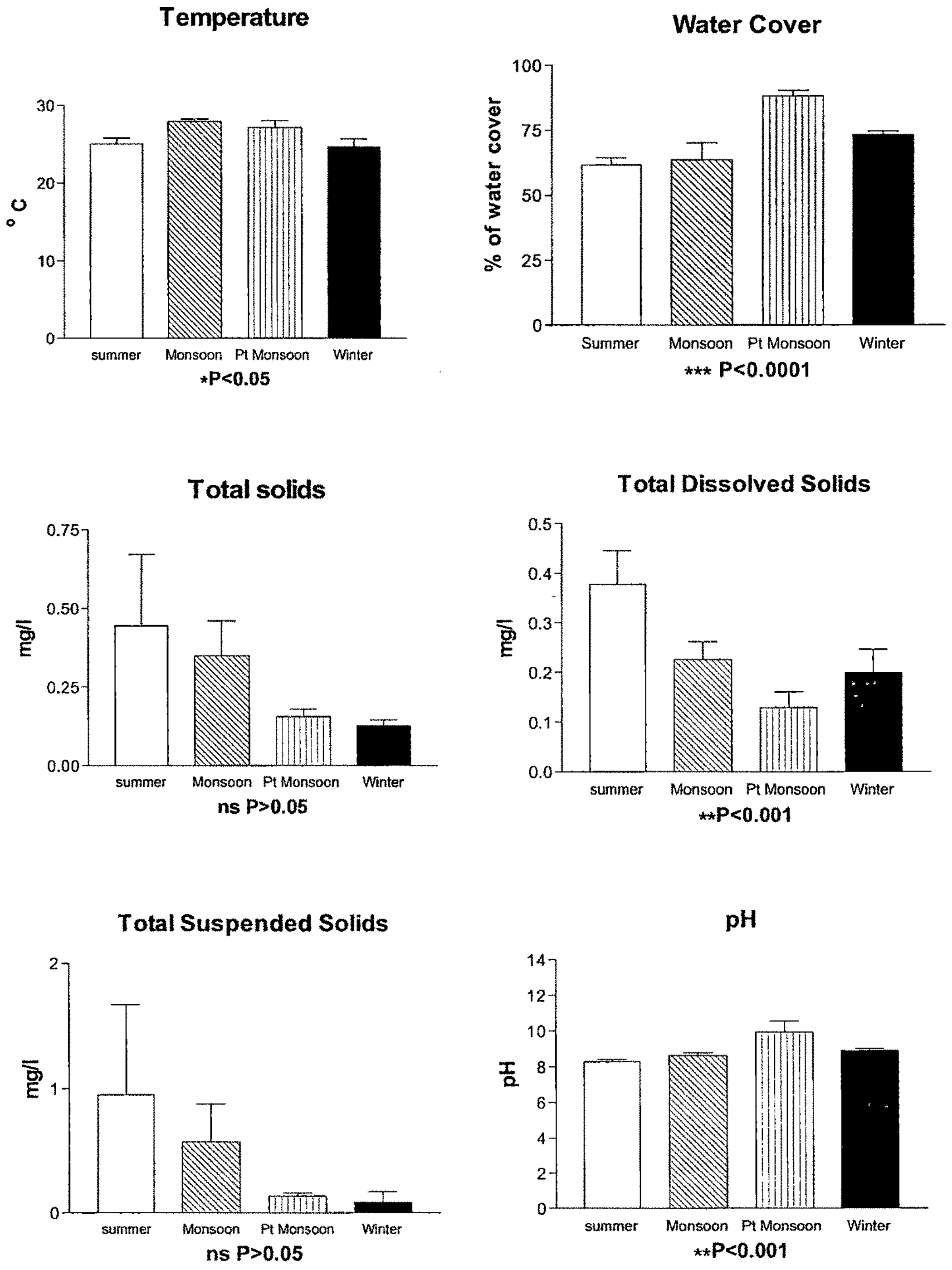


Figure 4.2b: The Seasonal variations in the different physical aggregate parameters at Timbi Irrigation Reservoir from February 2005 to March 2007.

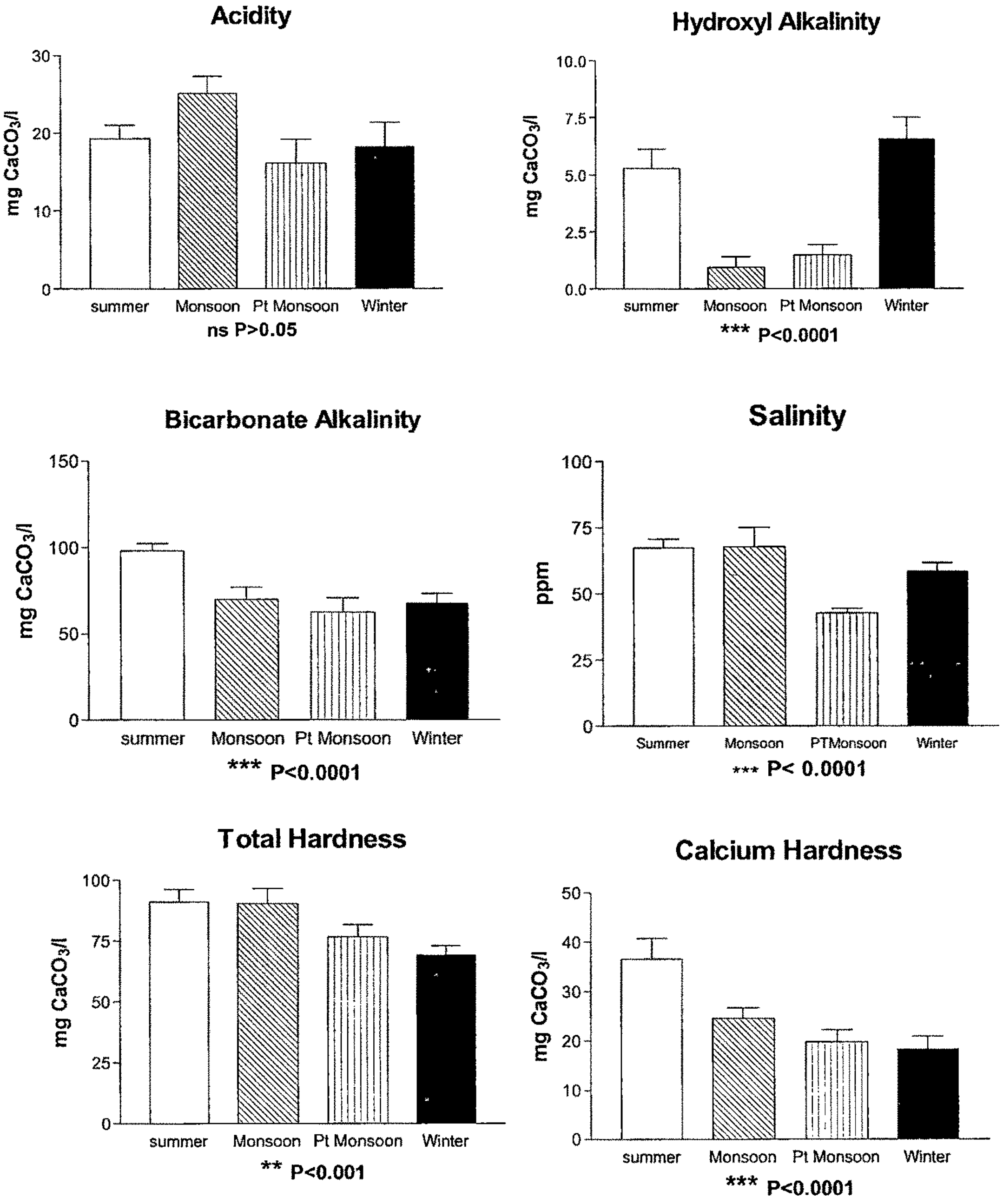
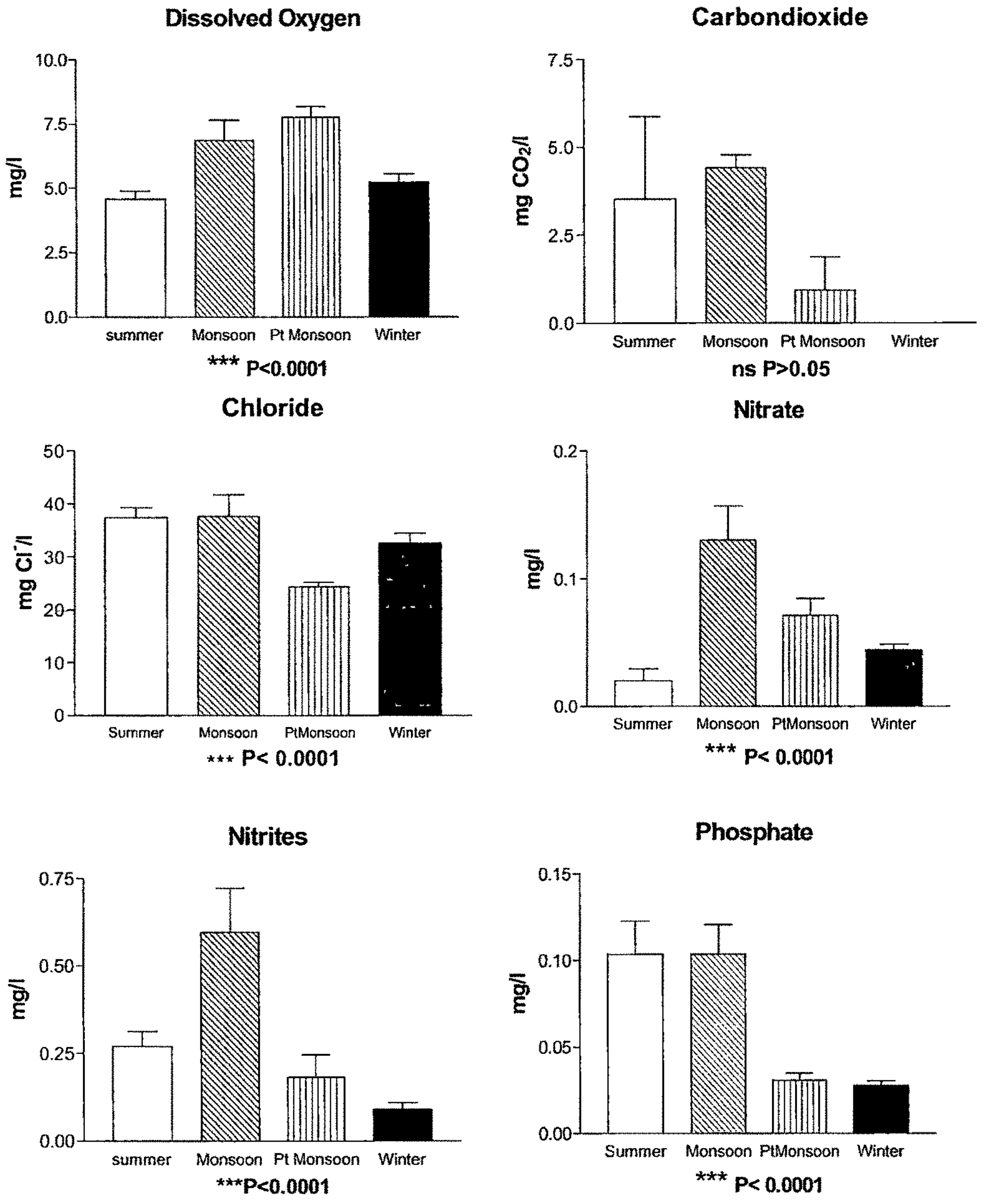


Figure 4.2c: The Seasonal variations in the different inorganic non-metallic constituents parameters at Timbi Irrigation Reservoir from February 2005 to March 2007.



pH sows significantly significant variations over the seasons ($P < 0.001$, $F_{3,\ 133}$ 3.3) at TIR (Fig. 4.2a). The pH was high during postmonsoon (9.9 ± 0.6) but declined marginally during winter (8.8 ± 0.12) and was maintained during summer (8.2 ± 0.14) as well as in monsoon (8.6 ± 0.16).

The changes in Acidity, Alkalinity, Hardness and Salinity are given in Fig. 4.2b. ***Acidity*** shows no significant variation ($P > 0.05$, $F_{3,\ 154}$ 1.9) throughout the seasons. However, the maximum acidity 25.0 ± 2.2 mg $CaCO_3$/l was noted during monsoon and minimum 16.1 ± 3.01 mg $CaCO_3$/l during postmonsoon. During summer and winter it was 19.2 ± 1.7 mg $CaCO_3$/l and 18.1 ± 3.19 mg $CaCO_3$/l respectively.

The ***Hydroxyl Alkalinity*** shows highly significant variations ($P < 0.0001$, $F_{3,\ 148}$ 13.98) when the means over the seasons are compared. The Hydroxyl alkalinity was high during winter (6.5 ± 0.94 mg $CaCO_3$/l) and summer (5.28 ± 0.83 mg $CaCO_3$/l) and minimum 0.94 ± 0.46 mg $CaCO_3$/l in monsoon and was almost maintained at 1.47±0.45 mg $CaCO_3$/l during post monsoon. The ***Bicarbonate Alkalinity*** also showed highly significant variations ($P < 0.0001$, $F_{3,\ 14}$ 7.3). The TIR water was more alkaline during summer (98.2 ± 4.2 mg $CaCO_3$/l), followed by monsoon (69.8 ± 7.2 mg $CaCO_3$/l) and minimum alkaline during postmonsoon (62.56 ± 8.07 mg $CaCO_3$/l) and alkalinity was low in winter (67.5±5.79 mg $CaCO_3$/l). The ***Salinity*** shows highly significant variations ($P < 0.0001$, $F_{3,\ 149}$ 7.1) over the four seasons. The Salinity at TIR was minimum during postmonsoon (42.6 ± 1.9 ppm) and started increasing during winter (58.5 ± 3.2 ppm) followed by summer (67.4 ± 3.3 ppm) and was maintained during monsoon (67.7 ± 7.3

ppm). ***Total Hardness*** shows significantly significant variation ($P < 0.001$, $F_{3,\ 151}$ 4.5) over the four seasons in both the years of study. The hardness was minimum during winter (69.31 ± 3.7 mg $CaCO_3$/l), and maximum during summer (91.09 ± 5.1 mg $CaCO_3$/l). It remained at 90.47 ± 6.09 mg $CaCO_3$/l in monsoon but declined during postmonsoon to 76.74 ± 5.04 mg $CaCO_3$/l. The ***Calcium Hardness*** at TIR varies highly significantly ($P < 0.0001$, $F_{3,\ 137}$ 7.5). Its highest concentrations were noted during summer (36.64 ± 4.15 mg $CaCO_3$/l) that decreased during monsoon (24.5 ± 2.1 mg $CaCO_3$/l), followed by post monsoon (19.76 ± 2.4 mg $CaCO_3$/l) and were minimum during winter (18.3 ± 2.6 mg $CaCO_3$/l).

The variations in inorganic nonmetallic constituents for TIR are given in Fig. 4.2c. The ***Dissolved Oxygen*** shows highly significant seasonal variations ($P < 0.0001$, $F_{3,\ 137}$ 8.7). The maximum 7.7 ± 0.42 mg/l dissolved oxygen was found during postmonsoon which declined during winter to 5.23 ± 0.31 mg/l. During summer it was minimum at 4.5 ± 0.30 mg/l but during monsoon it increased to 6.86 ± 0.78 mg/l. The variations in ***Carbondioxide*** were insignificant ($P > 0.05$, $F_{3,\ 14}$ 1.9) in TIR water. Maximum 4.4 ± 0.37 mg CO_2/l dissolve CO_2 was found during monsoon, which dropped down to lower level of 0.93 ± 0.93 mg CO_2/l during postmonsoon. No CO_2 was detected in TIR waters during winter but it appeared again in summer (3.5 ± 2.3 mg CO_2/l). The variations in ***Chloride*** concentrations are highly significant ($P < 0.0001$, $F_{3,\ 151}$ 6.3) over the four seasons at TIR (Fig. 4.2b). The chloride concentrations 24.37 ± 0.8 mg/l were lowest during postmonsoon which increased to 32.5 ± 1.8 mg/l during winter and 37.45 ± 1.8 mg/l during summer and was retained to this level during monsoon (37.6 ± 4.0 mg/l). The concentration of ***Nitrate***, one of the two nitrogen nutrients estimated, varies highly significantly ($P < 0.0001$, $F_{3,\ 77}$ 9.6) over the seasons. Nitrate concentration was maximum at 0.13 ± 0.02 mg/l during monsoon, followed by 0.07 ± 0.013mg/l during post monsoon and 0.04 ± 0.004 mg/l during winter and it was minimum during summer at 0.02 ± 0.009 mg/l. Concentration of ***Nitrite,*** the second nitrogen nutrient estimated, differed highly significantly across the seasons ($P < 0.0001$, $F_{3,\ 80}$ 10.2). The highest concentration 0.59 ± 0.12 mg/l of Nitrite was found during monsoon and minimum 0.09 ± 0.01 mg/l during winter. During summer it was 0.27 ± 0.04 mg/l and during post monsoon it was 0.18 ± 0.06 mg/l. The ***Phosphates*** show highly significant ($P < 0.0001$, $F_{3,\ 143}$ 7.6) variations over the seasons with maximum concentration 0.10 ± 0.01 mg/l during monsoon and minimum 0.02 ± 0.002 mg/l during winter. However in summer it was 0.10 ± 0.019 mg/l and in postmonsoon 0.03 ± 0.004 mg/l (Fig. 4.2c).

Masar Village Pond (MVP):

The seasonal variations in Temperature, water cover, Total Solids, Dissolved Solids and Suspended Solids, and pH are given in Fig. 4.3a. ***Temperature*** of MVP shows significantly significant variations ($P < 0.001$, $F_{3,\ 36}$ 6.3) and was highest in monsoon (27.64 ± 0.38 °C) and almost remained at the same level in postmonsoon but with greater fluctuations (26.2 ± 1.3 °C). It was minimum during winter with 22.8 ± 0.5 °C and at 26.0 ± 0.7 °C during summer. The ***Water cover*** varies with highly significant variations ($P < 0.0001$, $F_{3, 45}$ 11). Highest water cover 87.5 ± 2.1 % was noted during postmonsoon and lowest 47.8 ± 3.5 % during summer. It was 80.0 ± 10.3 % during monsoon and 68.3 ± 1.6 % during winter. ***Total Solids*** showed insignificant ($P > 0.05$, $F_{3, 40}$ 4.3) variations across the seasons and were maximum during summer (2.6 ± 0.4 mg/l) and minimum during postmonsoon (0.27 ± 0.03 mg/l). During monsoon and winter TS were 1.0 ± 0.5 mg/l and 1.4 ± 0.22 mg/l respectively. ***Total Dissolved Solids*** in MVP water varied insignificantly ($P > 0.05$, $F_{3, 22}$ 2.8) across the seasons and were minimum during monsoon (0.001 ± 0.0007 mg/l) and highest during summer (0.04 ± 0.01 mg/l). While during postmonsoon TDS were 0.003 ± 0.0005 mg/l and during winter 0.015 ± 0.001 mg/l. The ***Total Suspended Solids*** also showed insignificant ($P > 0.05$, $F_{3, 31}$ 2.11) variations over the seasons. Highest TSS were noted during summer (2.1 ± 0.4 mg/l), followed by monsoon (1.9 ± 0.8 mg/l) which dropped further to minimum during postmonsoon (0.2 ± 0.03 mg/l) and started increasing during winter (1.4 ± 0.22 mg/l). The ***pH*** shows significantly significant variations when the means over the seasons are compared ($P < 0.0001$, $F_{3, 58}$ 4.9). Maximum pH was noted in post monsoon (9.13 ± 0.20) that declined in winter (8.5 ± 0.01), and was maintained during summer (8.32 ± 0.02) but increased during monsoon (8.49 ± 0.28).).

The seasonal variations in the Acidity, Alkalinity, Salinity and Haradness for MVP are given in Fig. 4.3b. As ***Acidity*** kept on fluctuating in each seasons it in higher SEM and insignificant differences ($P > 0.05$, $F_{3,\ 129}$ 1.6). Acidity was maximum at MVP during winter (36.05 ± 3.2 mg $CaCO_3$/l) but it declined in summer (29.9 ± 3.2 mg $CaCO_3$/l) and monsoon (27.3 ± 2.1 mg $CaCO_3$/l) and reached to minimum level during postmonsoon (25.4 ± 4.6 mg $CaCO_3$/l). The ***Hydroxyl Alkalinity*** also did not vary significantly ($P > 0.05$, $F_{3,\ 149}$ 1) when the means over the seasons were compared as there were greater fluctuations in SEM. However, Hydroxyl Alkalinity was maximum during post monsoon at 1.7 ± 1.4 mg $CaCO_3$/l and minimum during winter when no hydroxyl alkalinity was obtained. During summer it was 1.2 ± 0.5 mg $CaCO_3$/l and during monsoon it declined to 0.41 ± 0.2 mg $CaCO_3$/l. The ***Bicarbonate Alkalinity*** showed highly significant variations over the seasons ($P < 0.0001$, $F_{3,\ 127}$ 12.6). The MVP water was more alkaline during winter (194.0 ± 32.4 mg $CaCO_3$/l) than summer (178.30± 11.59 mg $CaCO_3$/l) and was less alkaline during monsoon (70.74 ± 8.7 mg $CaCO_3$/l) and postmonsoon (74.1 ± 5.2 mg $CaCO_3$/l). The ***Salinity*** also shows highly significant ($P < 0.0001$, $F_{3,\ 128}$ 17.2) differences across the four seasons. The water of MVP is more saline and crosses the normal range of freshwater salinity (1000 ppm) during summer reaching maximum level (2672.0 ± 166.5 ppm). As the monsoon set in, the salinity decreased (1917.0 ± 464.7 ppm) and showed minimum level in postmonsoon (221.6 ± 56.0 ppm). As the rains were over, the salinity increased to 1101.0 ± 107.8 ppm during winter.

Fig. 4.3a: Seasonal Variations in different physical aggregate parameters at Masar Village Pond from February 05 to March 07.

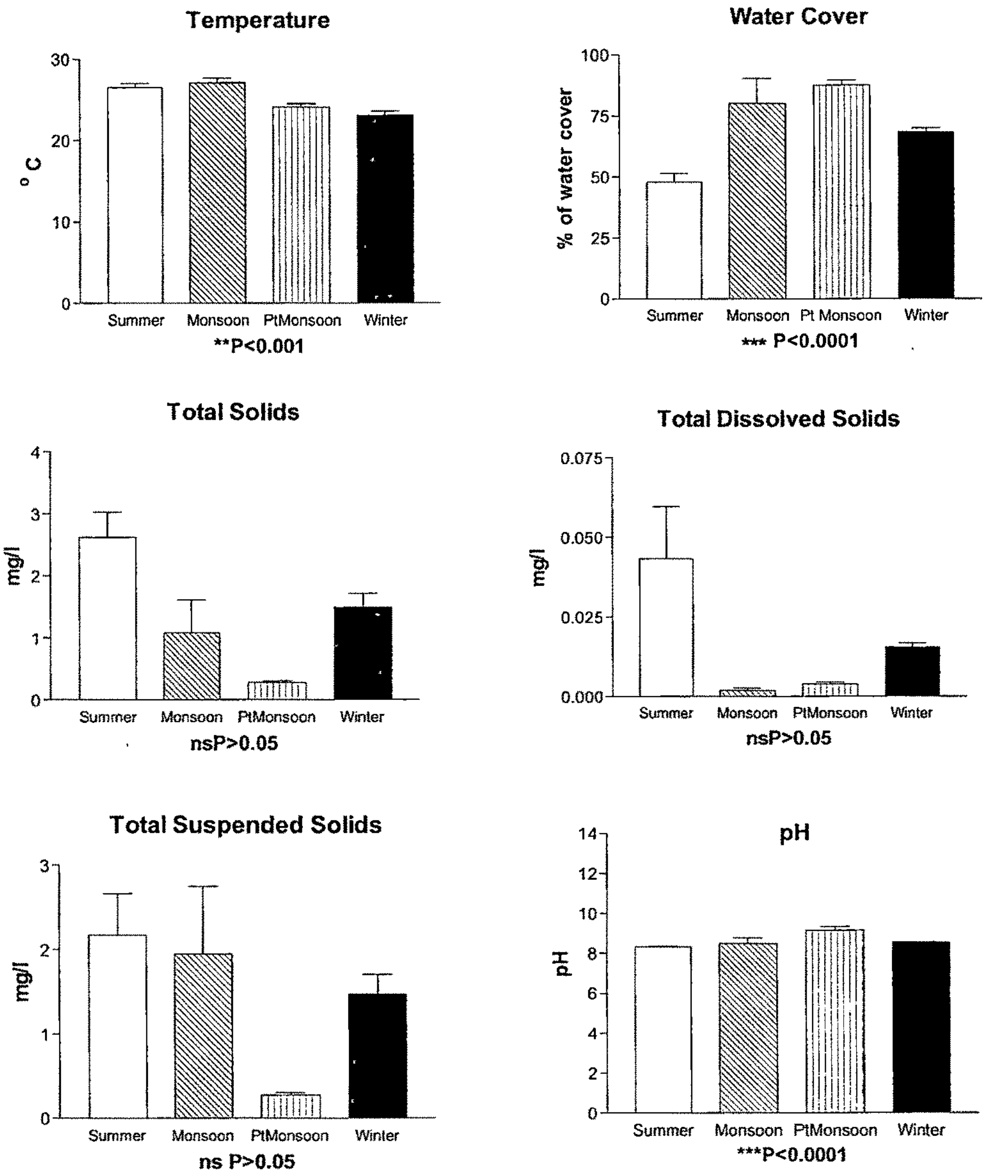


Fig. 4.3b: Seasonal Variations in different physical aggregate parameters at Masar Village Pond from February 05 to March 07.

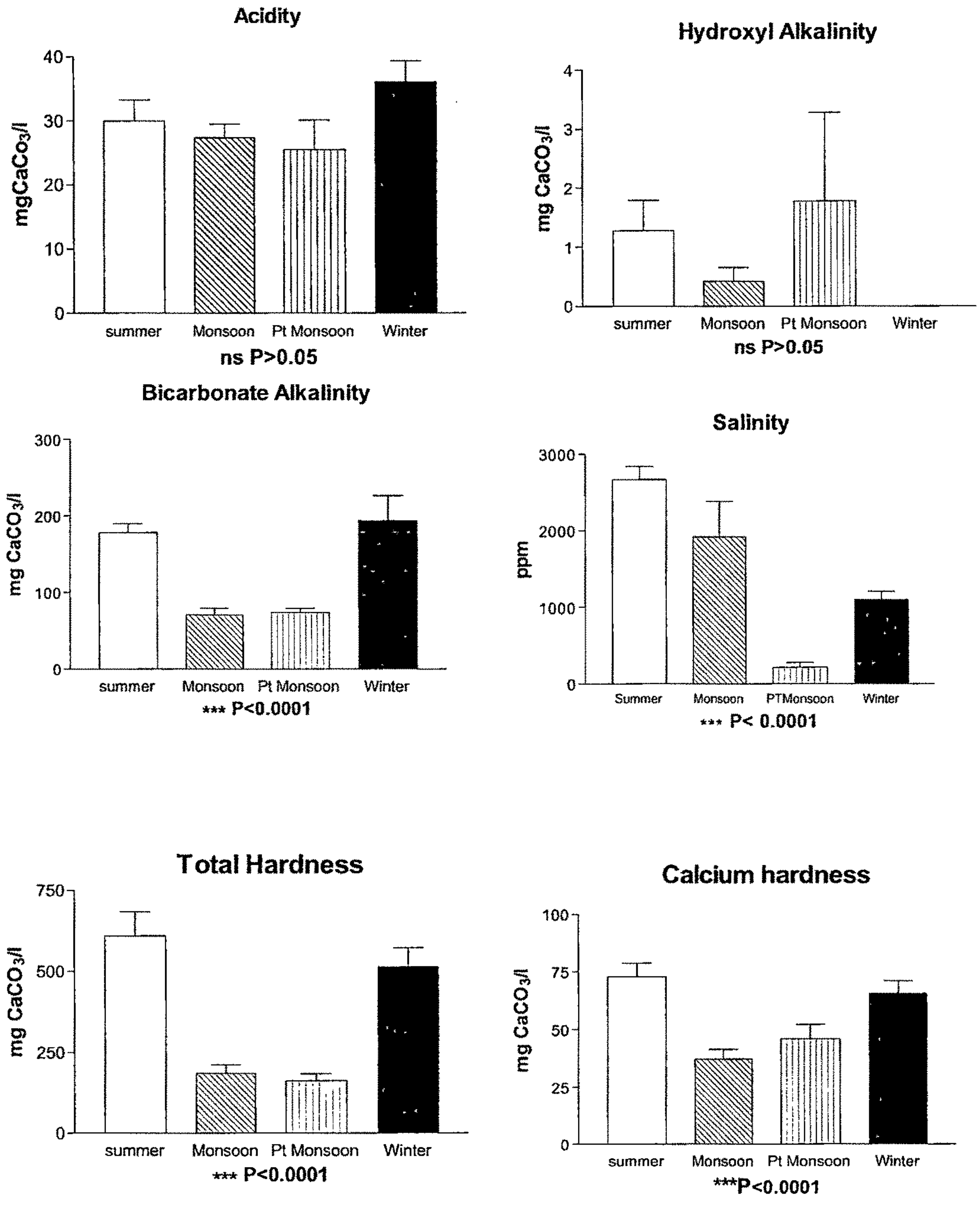
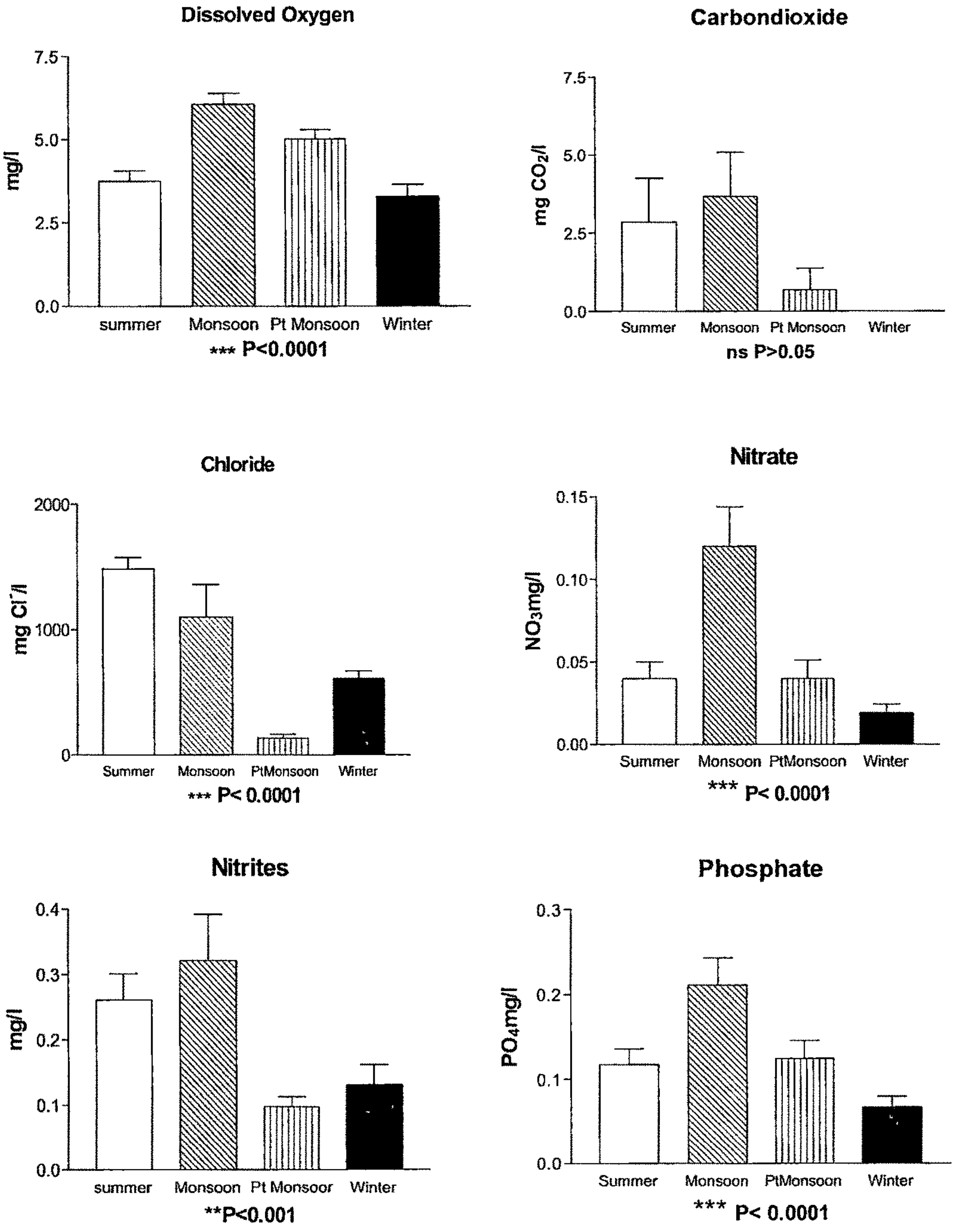


Fig. 4.3c: Seasonal Variations in different inorganic non-metallic constituents at Masar Village Pond from February 05 to March 07.



At MVP ***Total Hardness*** gave highly significant differences ($P < 0.0001$, $F_{3,\ 131}$ 17.4) across the four seasons. The Total hardness was lower during monsoon (186.80 ± 26.05 mg $CaCO_3$/l), as well as postmonsoon (163.80 ± 20.69 mg $CaCO_3$/l) but shooted up in winter and summer at 514.7 ± 59.31 mg $CaCO_3$/l and 608.80 ± 75.5 mg $CaCO_3$/l respectively. The ***Calcium Hardness*** also varies highly significantly at MVP ($P < 0.0001$, $F_{3,\ 115}$ 8.8) and recorded highest concentrations in summer 72.87 ± 5.92 mg $CaCO_3$/l, and minimum during monsoon 37.32 ± 4.07 mg $CaCO_3$/l. Rest of the year it was 46.08 ± 6.12 mg $CaCO_3$/l in post monsoon and 65.7 ± 5.40 mg $CaCO_3$/l in winter.

The seasonal variations in different inorganic nonmetallic constituents at MVP are given in Fig. 4.3c. The ***Dissolved Oxygen*** at MVP shows highly significant seasonal variations ($P < 0.0001$, $F_{3,\ 132}$ 14.3). It was maximum during monsoon (6.0 ± 0.3 mg/l), and decreased during postmonsoon (5.02 ± 0.28 mg/l) and reached to minimum level during winter (3.2 ± 0.35 mg/l). This level was maintained during summer (3.7 ± 0.31 mg/l). The ***Carbondioxide*** in the waters at MVP varied insignificantly ($P> 0.05$, $F_{3,\ 20}$ 2.8). Maximum Carbondioxide was noted during monsoon (3.6 ± 1.4 mg CO_2/l), and minimum (nil) during winter. During summer and postmonsoon carbondioxide levels were 2.8 ± 1.4 CO_2/l and 0.68 ± 0.68 CO_2/l respectively.

The ***Chloride*** variations are highly significant ($P < 0.0001$, $F_{3,\ 125}$ 16.5) over the four seasons at MVP. Lowest chloride content was noted during postmonsoon (132.6 ± 32.8 mg/l). But in winter it increased to 611.7 ± 59.9 mg/l and during summer it reached highest level of the year at 1484.0 ± 92.5 mg/l. With onset of the monsoon, it declined to 1099.0 ± 264.3 mg/l. The ***Nitrate*** concentration also varies highly significantly throughout the year ($P < 0.0001$, $F_{3, 77}$ 12.1). Nitrate concentration was highest during monsoon with 0.128 ± 0.02 mg/l but as the winter approached it reached to minimum level at 0.019 ± 0.00 mg/l. During summer it increased to 0.04 ± 0.009 mg/l while during post monsoon it was maintained at 0.04 ± 0.01 mg/l. The ***Nitrite*** concentration shows significantly significant variations throughout the year. ($P < 0.01$, $F_{3, 80}$ 5.7). The highest nitrite concentration was found during monsoon (0.32 ± 0.07 mg/l) that it dropped down to minimum during postmonsoon (0.09 ± 0.01 mg/l). However, it increased during winter (0.13 ± 0.03 mg/l) followed by summer (0.26 ± 0.04 mg/l). The ***Phosphate*** concentration also shows highly significant variations ($P < 0.0001$, $F_{3, 143}$ 7.6) being maximum during monsoon (0.210 ± 0.032 mg/l), it started declining during postmonsoon (0.12±0.021mg/l) and reached at minimum level of the year during winter (0.06 ± 0.01 mg/l) and was 0.11 ± 0.01 mg/l in summer.

Harni Village Pond (HVP):

The seasonal variations in the parameters studied are given in Fig. 4.4a., b and c.

As noted earlier for the three water bodies, at HVP also the ***Temperature*** shows highly significant variations ($P < 0.0001$, $F_{3, 30}$ 13.1) over the four seasons. Temperature of water was highest during monsoon (27.1 ± 0.6 °C) and lowest during winter (23.0 ± 0.49 °C) but fluctuated with 24.1 ± 0.4 °C and 26.5 ± 0.5 °C during postmonsoon and summer respectively. The ***Water cover*** also shows highly significant variations across the seasons ($P < 0.0001$, $F_{3,\ 143}$ 7). The highest water cover 95.0 ± 1.5 % was observed during post monsoon but decreased to 86.6 ± 2.2 % during winter and was recorded lowest 70.0 ± 4.6 % in summer. With the onset of monsoon the water cover reached to 88.1 ± 6.1 %. AT HVP ***Total Solids*** content did not show any significant variations ($P > 0.05$, $F_{3,\ 34}$ 0.8). Over the four seasons, they were maximum during monsoon (0.43 ± 0.10 mg/l) and minimum during postmonsoon (0.20 ± 0.02 mg/l), while during winter and summer TS were 0.29 ± 0.07 mg/l and 0.31 ± 0.09 mg/l respectively. ***Total dissolved solids*** also exhibited insignificant variations ($P > 0.05$, $F_{3,\ 19}$ 1.3) all throughout the year. In HVP water TDS were highest during summer (0.009 ± 0.006 mg/l), followed by monsoon (0.007 ± 0.001 mg/l). However, during postmonsoon and winter TDS were maintained 0.002 ± 0.0005 mg/l. The ***Total Suspended Solids*** also showed insignificant variations ($P > 0.05$, $F_{3,\ 17}$ 1.2) across the season at HVP. Being lowest during summer (0.15 ± 0.05 mg/l) it increased through monsoon (0.18 ± 0.06 mg/l) and postmonsoon (0.2 ± 0.02 mg/l) ultimately reaching to maximum level during winter (0.31 ± 0.10 mg/l).

As noted for other wetlands, ***pH*** of water at HVP was also always basic and remained between 8 and 9 with highly significant variations ($P < 0.0001$, $F_{3,\ 79}$ 36.9). The pH fluctuated within very narrow range and was higher during winter (8.9 ± 0.03) and summer (8.6 ± 0.04), dropped during monsoon (8.1 ± 0.05) but increased during post monsoon (8.5 ± 0.09). ***Acidity*** at HVP shows insignificant variations ($P > 0.05$, $F_{3,\,140}$ 1.2) over the seasons. However, among the seasons the maximum acidity was noted during summer (34.7 ± 7.4 mg $CaCO_3$/l) and minimum during post monsoon (21.53 ± 1.3 mg $CaCO_3$/l). In winter it was 28.1 ± 4.9 mg $CaCO_3$/l and in monsoon 27.0 ± 2.2 mg $CaCO_3$/l. The ***Hydroxyl alkalinity*** also does not show significant variations ($P > 0.05$, $F_{3,\,150}$ 1.6). However, the Hydroxyl alkalinity was high during summer (0.48 ± 0.29 mg $CaCO_3$/l) and monsoon (0.42 ± 0.24 mg $CaCO_3$/l) and was nil during post monsoon and winter. The ***Bicarbonate alkalinity*** showed highly significant variations over the seasons ($P < 0.0001$, $F_{3,\,141}$ 26.0). The HVP water was more alkaline during summer (162.30 ± 5.9 mg/l), followed by monsoon (124.9 ± 11.1 mg/l) and minimum alkaline during postmonsoon (73.41 ± 5.9 mg/l). During winter it increased to 119.9 ± 4.5 mg/l (Fig. 4.4b). The ***Salinity*** also shows highly significant variations over the seasons ($P < 0.0001$, $F_{3,\,139}$ 15.5) with highest 134.3 ± 7.8 ppm during summer but declined to 124.3 ± 8.6 ppm in monsoon followed by 79.1 ± 3.1 ppm during post monsoon but it increased in winter to 94.8 ± 3.1 ppm. The ***Total Hardness*** at HVP varied highly significantly ($P < 0.0001$, $F_{3,\,140}$ 10.9) over the four seasons in both the years of study. The hardness was low during monsoon (90.3 ± 4.2 mg $CaCO_3$/l) and post monsoon (90.6 ± 2.09 mg $CaCO_3$/l) and it increased during winter (106.0 ± 1.59 mg $CaCO_3$/l) and reached to its highest in summer (120.6 ± 6.7 mg $CaCO_3$/l l).

Figure 4.4a: Seasonal variations in different physical aggregate parameters at Harni Village Pond from March 05 to March 07.

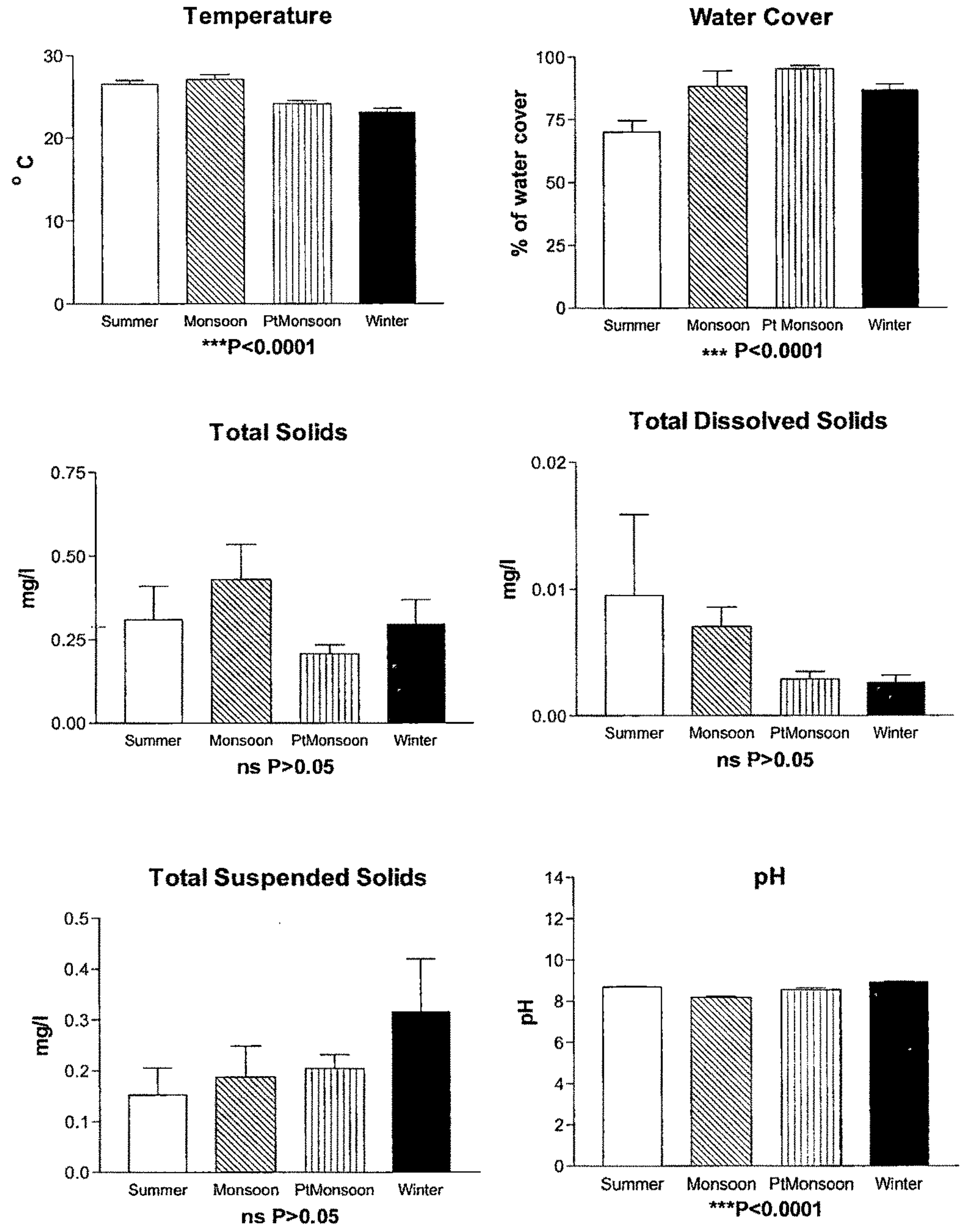


Figure 4.4b: Seasonal variations in different physical aggregate parameters at Harni Village Pond from March 05 to March 07.

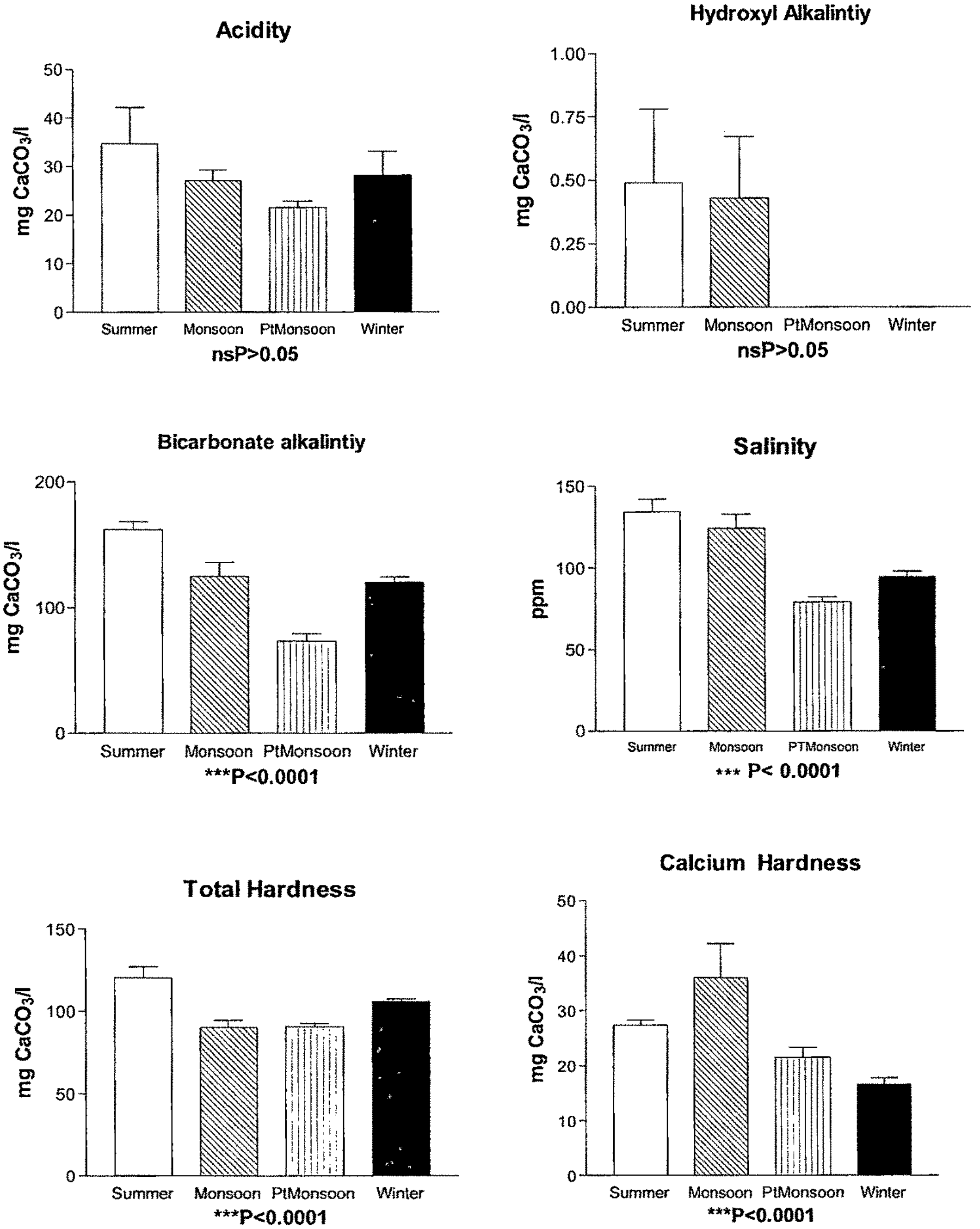
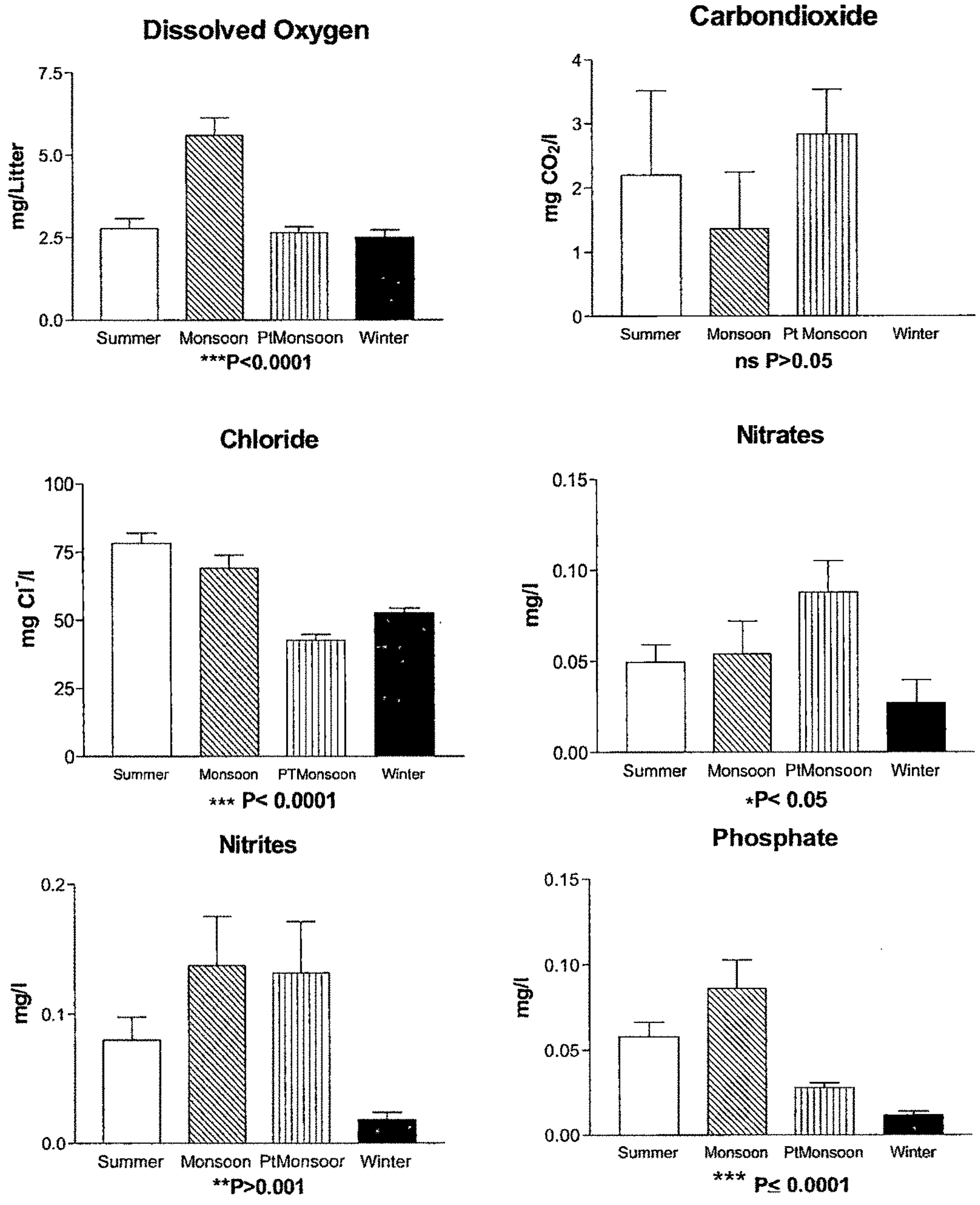


Figure 4.4c: Seasonal variations in different inorganic non-metallic constituents at Harni Village Pond from March 05 to March 07.



The ***Calcium Hardness*** also varies highly significantly ($P < 0.0001$, $F_{3,\ 121}$ 6.1) and the highest concentrations were observed during monsoon (36.01 ± 6.13 mg $CaCO_3$/l) and lowest during winter (16.5 ± 1.1 mg $CaCO_3$/l). During summer it was 27.41 ± 0.8 mg $CaCO_3$/l and during post monsoon it was 21.56 ± 1.78 mg $CaCO_3$/l.

As seen in Fig. 4.4c. the ***Dissolved Oxygen*** also shows highly significant seasonal variations ($P < 0.0001$, $F_{3,\ 129}$ 18.8). The maximum dissolved oxygen in HVP water was found during monsoon (5.59 ± 0.53 mg/l), which dropped to 2.6 ± 0.18 mg/l during postmonsoon and 2.5 ± 0.22 mg/l during winter and was maintained at 2.7 ± 0.30 mg/l during summer. Though, the ***Carbondioxide*** at HVP varies insignificantly ($P > 0.05$, $F_{3,\ 15}$ 1.5) it was maximum during postmonsoon (2.8 ± 0.7 mg CO_2/l) and absent during winter. In summer it was 2.2 ± 1.32 CO_2/l, but decreased further to 1.3 ± 0.87 CO_2/l in monsoon.

At HVP the ***Chloride*** variations are highly significant ($P < 0.0001$, $F_{3,\ 138}$ 23.2) over the four seasons. The highest chloride concentrations were noted during summer (78.3 ± 3.6 mg/l) when water level was minimum. This declined in monsoon (69.0 ± 4.7 mg/l) and reached to minimum level during postmonsoon (42.6 ± 2.1 mg/l) while it increased during winter (52.6 ± 1.7 mg/l). The ***Nitrate*** concentrations vary throughout the year significantly ($P < 0.05$, $F_{3,\ 77}$ 2.9). Nitrate concentration was highest during post monsoon (0.08 ± 0.01 mg/l) and minimum during winter 0.027 ± 0.01 mg/l. During summer it was 0.04 ± 0.009 mg/l and during monsoon it was 0.05 ± 0.018 mg/l. The ***Nitrite*** concentration shows significantly significant ($P < 0.001$, $F_{3,\ 77}$ 4.6) variations throughout the year. At HVP same concentrations of nitrites were noted during monsoon as well as postmonsoon (0.13 ± 0.03 mg/l). However, a significant decline in nitrite concentration was obtained during winter (0.01 ± 0.005 mg/l) which increased to 0.07 ± 0.01 mg/l during summer. The ***Phosphates*** show highly significant variations with $P < 0.0001$, $F_{3,\ 137}$ 12.06 over the four seasons. The maximum phosphate levels at HVP were noted during monsoon (0.08 ± 0.01 mg/l) and minimum in winter (0.01 ± 0.002 mg/l). During summer phosphate concentration was 0.05 ± 0.008 mg/l and during postmonsoon it was 0.02 ± 0.003 mg/l.

The intra correlation between various physicochemical parameters are given in Tables 1, 2, 3 and 4 for WIR, TIR, MVP and HVP respectively.

Table: 4.1. Intra Correlation between physico chemical parameters at Wadhwana Irrigation Reservoir during March 2005 to May 2007.

Correlations

	Acidity	Bicarbonate Alkalinity	Calcium Hardness	Chloride	Carbondioxide	Dissolved Oxygen	Total Hardness	Nitrites	Nitrates	pH	Hydroxyl Alkalinity	Phosphate	Salinity	TDS	Temperature	TS	TSS	Water Spread
Acidity	1.000																	
Bicarbonate Alkalinity	.591**	1.000																
Calcium Hardness	.306	.437**	1.000															
Chloride	.534**	.696**	.087	1.000														
Carbondioxide	-.345	-.242	.140	-.354	1.0													
Dissolved Oxygen	-.217	-.369*	-.423*	-.047	-.09	1.000												
Total Hardness	.508*	.619**	.365*	.559**	-.59*	-.110	1.000											
Nitrites	.035	.260	.344	.089	-.04	-.016	.325	1.000										
Nitrates	.308	.121	.187	.021	.540	.106	.206	.638**	1.00									
pH	-.106	-.441*	-.379	-.176	-.14	.186	-.404	-.413	-.230	1.000								
Hydroxyl Alkalinity	-.191	-.187	-.287	-.017	.413	.141	-.371*	-.343	-.040	.318	1.000							
Phosphate	-.443*	-.193	-.210	-.251	.064	-.297	-.413*	-.321	-.388	-.014	.138	1.00						
Salinity	.245	.559**	.145	.766**	-.35	-.050	.629**	.089	.021	-.152	.111	-.220	1.0					
TDS	.090	-.394	.020	.403	.a	.268	.007	.649	.300	.131	.021	-.268	.435	1.0				
Temperature	.071	.306*	.298	.048	.085	-.615**	.141	.139	-.122	-.170	-.115	.426**	.048	-.5	1.00			
TS	.295	.484*	.276	.461*	.255	-.018	.591**	.665*	.491	-.623*	-.361	-.353	.481*	-.4	.136	1.0		
TSS	-.003	-.050	-.160	.060	-.18	.133	-.095	.092	-.133	-.083	.018	.288	.060	.807*	.054	-.29	1.0	
Water Spread	.104	-.019	-.250	.236	-.16	.411**	.146	.290	.217	.028	.221	-.205	.237	.257	-.263	.467*	.196	1.0

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Table: 4.2. Intra Correlation between physico chemical parameters at Timbi Irrigation Reservoir during March 2005 to March 2007.

Correlations

	Acidity	Bicarbonate Alkalinity	Calcium Hardness	Chloride	Carbondioxide	Dissolved Oxygen	Total Hardness	Nitrites	Nitrates	pH	Hydroxyl Alkalinity	Phosphate	Salinity	TDS	Temperature	TS	TSS	Water Spread
Acidity	1.0																	
Bicarbonate Alkalinity	.436**	1.000																
Calcium Hardness	.274	.637**	1.000															
Chloride	.046	.482**	.248	1.0														
Carbondioxide	.00	.504	.850**	.452	1.00													
Dissolved Oxygen	-.15	-.477**	-.238	-.42**	-.439	1.00												
Total Hardness	.265	.535**	1.000**	.232	.683**	-.152	1.00											
Nitrites	.211	.106	.256	.343	.206	-.099	.088	1.00										
Nitrates	.311	.308	.376	.211	.242	-.079	.009	.934**	1.00									
pH	-.21	-.304	-.353	-.23	.033	.003	-.339	-.064	-.063	1.00								
Hydroxyl Alkalinity	-.41**	-.230	-.104	-.01	.350	-.137	-.012	.264	.123	.044	1.00							
Phosphate	-.02	.263	.030	.313*	.112	-.282	.090	-.399*	-.576*	-.091	.195	1.00						
Salinity	.046	.482**	.248	1.0**	.452	-.417**	.232	.343	.211	-.234	-.007	.313*	1.000					
TDS	-.08	.396	.206	.691**	.[a]	-.162	.233	-.474	.[a]	-.083	.161	.168	.691**	1.00				
Temperature	-.30	-.193	.095	.320	.458	-.007	.053	.208	.105	.067	.162	.129	.320	.412	1.00			
TS	.043	.230	.249	-.13	-.200	-.146	.264	.104	.978*	-.073	.041	-.038	-.133	.561*	-.263	1.00		
TSS	.106	.220	.435	.431*	.109	-.111	.451*	-.004	-.194	-.291	-.172	-.173	.431*	-.124	.278	-.331	1.0	
Water Spread	.182	-.267	-.082	-.56**	-.161	.434**	-.098	.122	.373	.227	-.315*	-.536**	-.559**	-.529*	-.481**	-.083	.12	1.0

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Table 4.3. Intra Correlation between physico chemical parameters at Masar Village Pond during March 2005 to March 2007.

Correlations

	Acidity	Bicarbonate Alkalinity	Calcium Hardness	Chloride	Carbondioxide	Dissolved Oxygen	Total Hardness	Nitrites	Nitrates	pH	Hydroxyl Alkalinity	Phosphate	Salinity	TDS	Temperature	TS	TSS	Water Spread
Acidity	1.00																	
Bicarbonate Alkalinity	.040	1.00																
Calcium Hardness	-.269	.393**	1.00															
Chloride	.047	.190	.210	1.00														
Carbondioxide	.019	.223	.108	.517**	1.00													
Dissolved Oxygen	-.229	-.350*	.027	-.098	-.033	1.00												
Total Hardness	-.159	.352*	.571**	.249	.407*	-.194	1.00											
Nitrites	-.033	.037	.221	.325	.073	.562**	-.136	1.00										
Nitrates	.018	-.302	-.059	.097	-.001	.525*	-.220	.764**	1.00									
pH	.145	.081	-.012	.103	.132	.157	.084	-.040	.183	1.00								
Hydroxyl Alkalinity	-.036	-.067	.161	.189	.192	.027	-.092	.431*	.119	-.270	1.00							
Phosphate	.081	.161	.120	.421**	.398	-.041	.130	.241	.219	-.027	.003	1.00						
Salinity	.047	.190	.210	1.00**	.517**	-.098	.249	.325	.097	.103	.189	.421**	1.00					
TDS	-.456	.165	-.159	.264	.[a]	-.511	-.036	-.516	.661	.185	.022	.262	.264	1.00				
Temperature	.069	.613**	.307	.593**	.483*	-.357*	.137	.157	-.124	.250	.025	.319*	.593**	.068	1.00			
TS	-.259	.461	.149	.085	-.528	-.335	-.095	-.250	-.155	.222	-.056	.121	.085	.989**	.008	1.00		
TSS	.074	-.133	-.012	-.310	-.165	.421*	-.227	.206	.331	.174	-.249	-.081	-.310	-.464	-.400*	.387	1.00	
Water Spread	-.107	-.411**	-.083	.269	-.085	.468**	-.043	.431*	.504*	.068	.237	.184	.269	-.402	-.139	-.368	.122	1.0

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Table 4.4 Intra Correlation between Physico chemical parameters at Harni Village Pond during March 2005 to March 2007.**Correlations**

Correlations

	Acidity	Bicarbonate Alkalinity	Calcium Hardness	Chloride	Carbondioxide	Dissolved Oxygen	Total Hardness	Nitrites	Nitrates	pH	Hydroxyl Alkalinity	Phosphate	Salinity	TDS	Temperature	TS	TSS	Water Spread
Acidity	1.00																	
Bicarbonate Alkalinity	.423**	1.00																
Calcium Hardness	-.063	.265	1.00															
Chloride	.266	.744**	.130	1.00														
Carbondioxide	-.130	-.193	-.162	.084	1.00													
Dissolved Oxygen	.151	-.001	-.286	.236	.124	1.00												
Total Hardness	.210	.362**	.328*	.370**	-.131	.011	1.00											
Nitrites	.029	-.031	-.069	.055	.053	.381	.132	1.00										
Nitrates	-.145	-.033	.086	-.088	.125	.235	-.146	.717**	1.00									
pH	-.194	-.623**	-.540**	-.461**	.560**	.101	-.311	.459	.472	1.00								
Hydroxyl Alkalinity	.682**	.435**	.129	.214	-.273	.075	.183	-.249	-.069	-.245	1.00							
Phosphate	-.204	.038	-.208	.172	-.124	.366*	-.212	-.246	-.209	-.167	-.072	1.00						
Salinity	.266	.744**	.130	1.00**	.084	.236	.370**	.055	-.088	-.461**	.214	.172	1.00					
TDS	-.484	-.035	.767**	.441	.a	-.337	-.034	-1.0**	.a	-.410	-.356	.335	.441	1.00				
Temperature	.400*	.622**	.449*	.405*	-.192	-.164	.359*	-.563*	-.287	-.613**	.569**	-.062	.405*	-.164	1.00			
TS	-.382	-.125	-.171	.155	.722*	-.010	-.255	-.424	.186	.350	-.524*	.213	.155	.287	-.365	1.00		
TSS	-.273	-.344	-.501	-.235	-.079	-.420	-.247	-.176	-.290	.021	-.345	.002	-.235	.a	-.161	-.007	1.00	
Water Spread	-.141	-.232	-.204	.148	.343	.443**	.034	.481*	.082	.267	-.445**	.199	.148	.478	-.553**	.332	-.018	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

DISCUSSION:

The physical and chemical parameters of water differ in a wetland depending on the inflow or out flow. The changes in water chemistry has been considered to exert influence in the distribution of many aquatic plant species (Catling *et al.,* 1986; Shay and Shay, 1986; Chee and Vitt, 1989; Lentz-Cipollini and Dunson, 2006). As animals depend directly or indirectly on plants, while studying waterfowls, it is pertinent to know water chemistry of a wetland. Concentrations of several components in water depend on temperature and hence result in the seasonal differences. The seasonal differences influence the temperature of water and are well exhibited as fluctuations in water temperature at all the wetlands. As expected the temperature is lowest at all the four wetland during winter. However, high temperature during monsoon could be attributed to higher temperatures of wet summer in semi arid zone of subtropical India. Water cools down slowly than the land. Water is received by the wetlands in this semi arid zone during monsoon. This water flows over land which is heated up during summer. While flowing over the land it absorbs heat from land resulting in cooling the land, as well as atmosphere, thus comparatively warmer water enters at all wetlands during monsoon (Fig. 4.1a, 4.2a, 4.3a and 4.4a). The Temperature is negatively correlated with water cover at TIR and HVP, the wetlands that are either located just outside (TIR) or in the city (urban) limits (HVP). Because of the concrete jungle the urban temperature is always higher than the rural environments. Both these wetlands receive water either in the form of Narmada Inundation (TIR) or sewage input

(HVP) while at MVP no such water entry occurs except rain water. Temperature is negatively correlated with TSS and DO at MVP whereas positively correlated with Bicarbonate alkalinity, Phosphates, Chlorides, CO_2 and Salinity. As the Temperature increases (during summer) the water cover decreases at MVP. MVP is just about 15 to 18 kms. from the Mahi river Estuary which is under the influence of estuarine tides. As said earlier, the effect of tides on the water chemistry of MVP needs to be investigated. At HVP temperature is probably having varied correlations with various components of water depending on anthropogenic as well as pollution pressure.

Hydrogen ion activity pH is one of the several important components. In the present study pH and water levels are directly correlated at all the wetlands studied except HVP. At HVP pH was lowest during monsoon when input of water was high. HVP is the smallest of all the four water bodies studied and is under heavy pressures of urbanization and pollutions. The anthropogenic pressure in the form of sewage disposal is visible at HVP (Plate XII) and is expected to change the pH of wetland. The lower alkaline pH at other waterbodies could be because of increase in Carbondioxide as is also reported by Powers (1930). This might have resulted due to the low photosynthetic activity of autotrophs during winter as the photoperiod is of short duration.

No correlation of pH was established with majority of parameters studied at WIR, TIR and MVP. However at HVP, the urban polluted pond, pH is negatively correlated with Bicarbonate Alkalinity, Calcium Hardness, Chlorides, Carbondioxide, Salinity and Temperature (Table. 4.1, 4.2, 4.3, 4.4).

The seasonal significant variations in **TS** at both the irrigation reservoirs are mainly due to frequent inundation of water from Sardar Sarovar dam on Narmada river This either brings the solids or agitates the water disturbing the solids. At both the village ponds, the main water source is only the rain during monsoon. Once the total solids settle down the variations in TS over the seasons are nonsignificant. TS is high in monsoon at WIR and HVP as the inflow is high during monsoon, whereas TS is higher at TIR and MVP during summer where wallowing of cattle in shallow water during scorching heat of summer is observed and thus, the disturbance to the settled solids is common. No correlation is established for Total Solids, Total Dissolved Solids and Total Suspended Solids at all the four freshwater wetlands of semiarid zone of Gujarat. However, seasonal variations in the said parameters are noted and needs to be correlated with reference to seasons as well as soil parameter, pollution, *etc.*

A wide variety of organisms including algae, macrophyte, zooplankton, macro invertebrates, amphibians, and fishes are adversely affected by acidification (Haines, 1981; Hunter *et al.*, 1986). **Acidity** is minimum during postmonsoon at all the wetlands as this is the period immediately after precipitation which leads to dilution. However, during monsoon it was maximum at both the irrigation reservoirs, this could be because of the initial acidic rains as well as agricultural run off which might have increased the hydrogen ion concentration. This higher acidity was always lower than the acidity of waters at HVP which is under heavy urban as well as pollution pressures at any time of the year. No common correlation of acidity of water could be established at the wetlands of semi arid zone. However, at WIR, TIR and HVP, acidity could be correlated positively with Bicarbonate alkalinity. At WIR, the largest wetland studied, acidity was positively correlated with bicarbonate alkalinity, total hardness and chlorides, but is negatively correlated with phosphates. The analysis of soil can provide better correlation of acidity with other components of water chemistry.

During monsoon the acidity increased but simultaneously **hydroxyl alkalinity** decreased at WIR and TIR. Further, both these reservoirs are receiving Narmada water under the same schedule and mainly during winter when the Rabi crop is in developing stage. However, the village ponds which do not receive Narmada water showed different pattern with higher hydroxyl alkalinity during postmonsoon at MVP and in summer at Harni. MVP is not much under anthropogenic pressures. While HVP is under high pressure of urbanization. An interesting observation was noted at both the village ponds. Here the hydroxyl alkalinity was 'zero' during winter. At both the irrigation reservoirs (WIR and TIR) water is more alkaline as compared to the village ponds. At MVP and HVP as both receive domestic sewage, lowering of the pH results. However, at MVP the agricultural run off results in further lowering the alkaline conditions. The WIR water was always more alkaline. WIR spreads in large area with deep as well as shallow waters. Water is collected from dam side where water is deeper and vegetation is low compared to shallow sides. According to Schutte and Elsworth (1954) large fluctuations in pH occur during hot sunny weather in dense masses of vegetation while in sparse vegetation these changes are not pronounced. Thus, in the deeper water with sparse vegetation of WIR minimum fluctuation in alkalinity are noted. The dependency of human habitations on the wetland for the domestic use is greater at TIR, MVP and HVP probably lowering the alkalinity of water compared to that at WIR.

The effect of rains in lowering Bicarbonate Alkalinity is noted during post monsoon at WIR, TIR and HVP, and during monsoon at MVP. At MVP during both the years overflowing of water probably washed away bicarbonates earlier than the other two water bodies. However, high concentration of bicarbonates are noted during different seasons at the water bodies studied with high bicarbonate during monsoon at WIR, during summer at TIR and HVP, and during winter at MVP. All the wetlands are under varied anthropogenic pressures; WIR with minimum pressure, TIR moderate and HVP with heavy pressure and all the three also receive water throughout the year either in the form of Narmada inundation (WIR and TIR) or sewage disposal (HVP). These three wetlands are freshwater wetlands whereas MVP is the only one which is not receiving additional water throughout the year and is probably under the underground influence of high tides of Mahi river estuary. This needs further investigations.

The alkalinity is mainly in the form of bicarbonates (Hannan *et al.*, 1979) and hence the bicarbonate alkalinity is positively correlated with Total Hardness at

WIR, TIR and HVP while with Calcium Hardness at WIR, TIR and MVP. Further a negative correlation of Bicarbonate with Dissolved Oxygen at WIR, TIR and MVP is observed but no such correlation is established at Harni pond. Here, the influence of urban pressure distinguishes HVP from other water bodies. However, at three waterbodies away form estuarine influence the Bicarbonate alkalinity is positively correlated with Salinity.

Salinity is having a major effect on community structure and primary production. As salinity is calculated from the chloride value (chloride X 1.0855 is salinity), both follow the same trend. The decrease in water level/ water cover due to evaporation during summer leads to the higher concentration of chlorides, in turn results in higher salinity. But the high water levels in postmonsoon due to precipitation of water leads to dilution of the chloride ions and as a result it is found to be minimum at TIR, MVP and HVP. An opposite situation exists at WIR. The frequent inundation of Narmada water makes WIR perennial pond with comparatively extended hydroperiod and hence occurrence of low chloride concentrations. The salinity at MVP exceeds the normal range of freshwater salinity (1000 ppm). The influence of tide in Mahi river estuary (about 15-20 kms. away) (one of the highest tidal fluctuations in the world) and its probable ground level influence in the pond especially during summer needs to be explored. Highest high tide of the year during the full moon or the no moon day also occur during summer on the west coast of India just before monsoon sets in and many coastal areas in Gulf of Cambay where Mahi river opens are affected because of this. Chloride and Salinity are correlated with Temperature at MVP and HVP. Only at TIR Chloride is positively correlated with Phosphates, TDS, TSS and negatively correlated with Dissolved Oxygen as well as water cover.

Total Hardness is highest during summer at all the wetlands except WIR where effect of Narmada inundation is more pronounced. Here, though the water level decreases during summer, the water cover is large. The calcium and magnesium are the main constituents contributing to the hardness of the water being inversely proportional to the water level (Lentz-Ciploni and Dunson, 2006), thus, during summer as the water level is low the hardness is high. In monsoon the water level is high but due to the sediment leaching the hardness increases at WIR. The minimum hardness varied at all the wetlands with expected difference at the most polluted wetland with urban pressures *i.e.* HVP. The lowest hardness at MVP during postmonsoon and during winter at TIR could not be justified in present study. At MVP the hardness is very high as compared to other wetlands because of its location nearer to Mahi River Estuary. As the influence of tidal influx is proposed at MVP probably Chloride is not correlated with Total Hardness. The other sites which are interior in position show positive correlation between Chloride and Total Hardness. Chloride occurs mainly in the form of Sodium Chloride. Sodium levels in MVP water under the influence of tidal influx needs further evaluation.

Oxygen consumption in water is due to respiration, decomposition and the oxidation of dissolved organic compounds (Hannan *et al.*, 1979). During summer on one hand the decomposition of the dead organic matter is high utilizing the dissolved oxygen and on other hand the temperature is higher which may reduce oxygen. It is known that the dead vegetation can affect the dissolved oxygen content in two ways (a) as the vegetation dies it floats on the surface of the water decreasing exposed surface area and reducing the diffusion of oxygen into the water and (b) the decomposition will increase the oxygen demand (oxygen consumption) resulting in further decline in the dissolved oxygen (Reddy, 1981). The restricted circulation of summer stratification results into oxygen depletion in the hypolimnion (upper layer) of a lake (Happey, 1970). This type of situation is created at WIR during summer and hence the dissolved oxygen is lowest during summer. The dissolved oxygen is found to be highest during monsoon at both the village ponds and during postmonsoon at both the irrigation reservoirs. This can be attributed to increased photosynthetic activities as well as increased mixing of atmospheric oxygen in disturbed water during monsoon and postmonsoon (Reddy, 1981) when more nutrients are mixed in the water. As the fresh water enters during this season, more nutrients are brought with run off water, probably increasing photosynthetic activities. However, such condition probably occurs at both the irrigation reservoir during postmonsoon when water is almost stable and at maximum level (Plate IV.A, IV.B, VII.B and VIII.A). The submergent and emergent vegetation grow to their maximum causing increase in photosynthetic activity.

Nitrate occurs in fewer amounts in surface waters. It is essential nutrient for synthetic autotrophs and is also identified as growth limiting nutrient. Nitrite is an intermediate oxidation state of Nitrogen in the oxidation of Ammonia to Nitrate as well as in reduction. Such oxidation and reduction may occur in waste water. The sediments form the largest pool of nitrogen in wetlands (Bowden, 1984; 1987) and from the sediments the nutrients leach out increasing the total concentration of nutrients of the wetland. Nitrate content was maximum during summer at WIR, when water cover is minimum. This is the period of large congregation of resident species of birds in the years after Narmada Inundation started (Padate *et al.*, 2008). Probably the accumulation of guano influences the Nitrate content in water (Bosman *et al.*, 1986). Though the congregation of birds is much higher during winter, this is the time when inundation of water from Narmada and distribution of water for irrigation (inflow as well as outflow) is taking place almost simultaneously thus reducing the concentration of Nitrates. At TIR, MVP and at HVP no such specific conclusion could be made regarding Nitrate concentrations.

The highest **Nitrite** concentrations found during monsoon at all the wetlands could be because of release of nitrogen from the sediments on the arrival of fresh water in monsoon. Whereas the minimum concentration noted during winter at WIR, TIR and HVP could be because of utilization of Nitrogen by plants for growth during moderate winter of subtropical zone. According to Yang *et al* (2001), for the growth of plant absorption of Nitrogen is maximum thereby resulting into reduction of the total Nitrite content in water. Though the photoperiod is short during winter, wetlands occur in subtropical belt that receives adequate sunlight.

The **Phosphate** content followed a parallel trend at all the wetlands *i.e.* the phosphate content is maximum during Monsoon. Phosphorous from soil particles is reabsorbed in water as a result of soil erosion (Khan and Ansari, 2005). Phosphates are also related to the locking by macrophytes and phytoplankton during their bloom decreasing their level in water (Kant and Raina, 1990). The maximum phosphates during monsoon at all the wetlands studied could be correlated to the release of PO_4^{-3} to water from soil when new water arrives during monsoon with some soil erosion. The minimum PO_4^{-3} during winter at all the wetlands except WIR where it was minimum during postmonsoon indicates growth of macrophytes and phytoplankton which occurs in larger wetland (WIR) during post monsoon. Here there is maximum inundation with Narmada water creating fluctuating PO_4^{-3} levels. The Phosphate is mainly of concern for the limnological studies and also for the water birds (Filella *et al.*, 2006).

Water cover is positively correlated with Dissolved Oxygen at all the four wetlands studied. At WIR water cover is also positively correlated with Total Solids. The frequent inundation from Narmada water is more pronounced here. Though, TIR is also inundated with water no correlation is established here. The water Nitrites are positively correlated at MVP and HVP but not at WIR and TIR. A relation of water cover and Nitrate and Nitrite and vegetation needs evaluation.

As the study sites fall in the semi arid region the impact of various seasons is noted on most of the parameters. The climate of this region, with anthropogenic activities as well as Narmada inundation plays important role in the water chemistry. The type of the wetland whether an irrigation reservoir or a village pond also has impact on the abiotic parameters. The impact of the geographical positioning is striking at MVP as the parameters like the Chloride, Salinity, Total Hardness and Calcium Hardness show variations because of the ground water flow from the near by Mahi estuary.

The chemical changes because of the interdependency of various physical as well as inorganic component show varied correlation in this semi arid zone of central Gujarat, India.

CONCLUSION:

The abiotic constituents of a wetland ecosystem changes according to season and in turn influence the quality of the wetland as well as the biota supported by the it. The various physical aggregate parameters and the inorganic nonmetallic constituents in wetlands of semi arid zone of Gujarat show variations according to the season. In addition to this, Narmada inundation, geographic location and the anthropogenic pressure also influence water chemistry The influence of Narmada inundation is noted at WIR whereas, Narmada inundation and proximity to urban conditions at TIR. Influence of proximity to Mahi River Estuary, is evident at MVP. Urban pressures mainly at HVP with pronounced variations in abiotic parameters were observed. The positive and negative intra correlation of abiotic parameters of water chemistry indicates that in Semi arid zone of Gujarat no single common abiotic parameter could be correlated to biotic parameters studied.